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UPPER POTOMAC RIVER BASIN WATER QUALITY ASSESSMENT

Johan A. Aalto, et al

Federal Water Pollution Control Administration
Annapolis, Maryland

November 1969

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U.S. DEPARTMENT OF THE INTERIOR
FEDERAL WATER POLLUTION
CONTROL ADMINISTRATION
MIDDLE ATLANTIC REGION

UPPER POTOMAC RIVER BASIN
WATER QUALITY ASSESSMENT

Johan A. Aalto
Leo J. Clark
Norbert A. Jaworski

November 1969

PENNSYLVANIA
MARYLAND
DISTRICT OF COLUMBIA
VIRGINIA
NORTH CAROLINA
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Middle Atlantic Region
Federal Water Pollution Control Administration
U. S. Department of the Interior

Technical Report No. 17

UPPER POTOMAC RIVER BASIN

WATER QUALITY ASSESSMENT

Johan A. Aalto
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FOREWORD

An investigation of the water quality problems in the upper Potomac Estuary revealed an obvious direct relationship between population and pollution. In the process of determining waste loading limits for the Washington Metropolitan Area to maintain approved state water quality standards, the logical question of upstream contributions to the loadings arises. Are high bacterial counts eliminated or effectively reduced by natural means in the river? Are toxic materials such as pesticides or metallic compounds adequately diluted? Are organic wastes sufficiently oxidized? In short, will the water entering the Potomac Estuary from the river upstream add significantly to the existing pollution problems in the estuary?

In order to distribute the cost of correctional actions equitably, it is necessary to assess the water quality contributions from the upstream Potomac River.

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CHAPTER II

INTRODUCTION

A. PURPOSE AND SCOPE

The third session of the conference on pollution of the Potomac River-Washington Metropolitan Area Enforcement Conference which convened in April and May of 1969 resulted in a set of recommendations for future corrective action.

As a result of questions raised concerning the relative contribution of upstream problems to water quality in the metropolitan area, a recommendation to include a joint study of the entire Potomac basin was adopted by the conferees. The Interstate Commission on the Potomac River Basin was requested to call a meeting to consider these upstream contributions.

This is one of four technical reports prepared by the Chesapeake Technical Support Laboratory (CTSL) of the Middle Atlantic Region (MAR), Federal Water Pollution Control Administration (FWPCA) of the Department of the Interior to explore the general water quality in the upper Potomac River basin. The other reports include inventories of municipal and industrial waste discharges, nutrient studies and effects of mine drainage.

B. ACKNOWLEDGMENTS

To supplement the special studies of CTSL, data from governmental, industrial, and institutional sources were collected, evaluated, and subsequently incorporated into this technical report. The cooperation of the following agencies is gratefully acknowledged:

District of Columbia, Department of Public Health

District of Columbia, Department of Sanitary Engineering

Maryland Department of Water Resources

Pennsylvania State Department of Health

U. S. Army Corps of Engineers, Washington Aqueduct Division

U. S. Geological Survey, Department of the Interior

Virginia Water Control Board

West Virginia Department of Natural Resources

CHAPTER III

SUMMARY AND CONCLUSIONS

The need for a water quality assessment of the upper Potomac basin was the outcome of a recommendation adopted by the conferees of the Potomac River-Washington Metropolitan Area Enforcement Conference. The purpose of the assessment was to investigate pollution conditions in the upper basin and to evaluate their possible contributions to water quality problems of the Potomac Estuary. This report is based on historical data supplemented by two special surveys conducted in July and August 1969. The findings are summarized below:

1. The total coliform and fecal coliform concentrations throughout the upper Potomac basin vary considerably.

2. In the Monocacy basin, persistently high bacterial densities have been observed. Total and fecal coliform counts in excess of 160,000 MPN/100ml* are common throughout this basin, particularly during high flow periods.

3. Fecal coliform counts were also unusually high in the North Branch Potomac below Luke and Amcelle, Maryland (90,000), the South Branch Potomac below Petersburg and Moorefield, West Virginia (50,000), the Conococheague Creek below Chambersburg, Pennsylvania (160,000), and the Antietam Creek below Waynesboro, Pennsylvania and Hagerstown, Maryland in 1969.

* All coliform counts in this report are the most probable number (MPN) per 100ml.

4. In the Shenandoah sub-basin, high fecal coliform densities occurred in the North River near Harrisonburg, Virginia (160,000), the Middle River near Staunton, Virginia (160,000), and the North Fork Shenandoah River below Timberville, New Market, and Edinburg, Virginia (50,000) in 1969.

5. The water quality standards for coliform bacteria were frequently contravened in the North Branch Potomac, South Branch Potomac, Conococheague Creek, Opequon Creek, Antietam Creek, Shenandoah River (including both the North and South Forks), Monocacy River and the main stem Potomac River.

6. Although extensive bacteriological data were collected throughout the upper Potomac basin, it is difficult to determine their significance unless the relative coliform contributions from waste treatment plant effluents and from various types of land runoff can be established.

7. Three areas in the upper Potomac where low dissolved oxygen occurred are North Branch Potomac River from Luke, Maryland to Spring Gap, West Virginia (approximately 45 miles), Monocacy River downstream from Frederick, and the South River of the Shenandoah downstream from Waynesboro, Virginia. All of these areas were characterized by DO levels below 1.0 mg/l during low flow summer conditions.

8. Less critical areas where future DO monitoring is also warranted include the North Fork Shenandoah River below Timberville, the South Fork Shenandoah River below Elkton, the main stem Shenandoah below Front Royal, and Antietam Creek below Hagerstown.

9. Limited data from the upper Potomac indicate that most of the determinations for chlorinated hydrocarbon pesticides were negative. However, significant quantities of dieldrin and DDT (0.666 ug/l and 0.17 ug/l) were measured in Antietam Creek during August 1969. Maximum DDT, dieldrin, and endrin concentrations in the Potomac River at Great Falls for a ten-year period of record were 0.038 ug/l, 0.04 ug/l, and 0.094 ug/l, respectively. The endrin concentration exceeds the recommended criteria for fish and aquatic life (0.05 ug/l).

10. A definite need exists for additional surveillance of pesticides in the Potomac basin to isolate the sources and to determine the quantities contributed over a complete hydrologic cycle.

11. Thermal pollution does not constitute a significant problem in the upper Potomac basin at the present time.

12. Potential thermal problems exist in the North Branch Potomac below the large industries at Luke and Amcelle and below the steam-electric generating plant near Cumberland. Future studies of stream temperatures and ecological conditions will be necessary in those areas of the North Branch. Studies should also be planned for the Mount Storm Reservoir below the power plant, and for the main stem Potomac below the power plants at Williamsport and Dickerson.

13. Mine drainage in the North Branch Potomac basin is contributed primarily from nine tributary watersheds in West Virginia and Maryland upstream from Luke, Maryland. The effects of mine drainage

while normally confined to the North Branch Potomac River above Cumberland can be detected throughout most of the North Branch Potomac River during periods of high runoff.

14. More than 40 miles of the North Branch and more than 100 miles of tributary streams are characterized by high acidity, low pH, and excessive metals and solids which have rendered these streams a "biological desert" and unsuitable for most beneficial water uses.

15. Based upon a preliminary appraisal, the annual expenditure required to control most of the mine drainage in the North Branch Potomac basin is estimated at $5,000,000.

16. In the upper Potomac basin approximately 18,000 lbs/day of total phosphate (PO_4) and 11,000 lbs/day of total Kjeldahl nitrogen (TKN) originate in 256 wastewater discharges. Approximately 7,700 lbs/day of the above total PO_4 and 4,600 lbs/day of the above TKN were from industrial wastewater discharges.

17. The various nutrient concentrations were generally high in the Opequon and Antietam Creeks and the Monocacy River. These streams were also characterized by local heavy rooted aquatic and phytoplankton growths.

18. It appears that, while the nutrient contributions from land runoff (agricultural and urban) are significant, the most pronounced increases are from controllable point-source waste loadings.

19. Based upon both long-term and recent survey data, total and fecal coliforms in the Potomac River at Great Falls are frequently greater than 1,000. Maximum fecal coliform concentrations of

140,000 and 85,000 were measured during July and August 1968, respectively.

20. The BOD concentrations at Great Falls are low, usually ranging from 2 to 4 mg/l. However, on a pounds/day basis the fresh water inflow represented a significant organic loading to the estuary. During the period from January to August 1969, the average BOD loading at Great Falls was greater than 100,000 lbs/day--or 45 percent of the total BOD discharged into the upper Potomac Estuary from all sources.

21. The average monthly dissolved oxygen (DO) concentrations at Great Falls over the past ten years were generally greater than 6.0 mg/l. The water quality standards specify a minimum of 5.0 mg/l.

22. During the period from January to August 1969, the average upper basin loadings of total nitrogen and total phosphorus to the Potomac Estuary were 27,000 lbs/day as N and 3,600 lbs/day as P, or 34 and 14 percent, respectively, of the total loads to the estuary.

CHAPTER IV

BASIN DESCRIPTION

A. HISTORY

Development and population growth in the Potomac River basin upstream from Washington, D. C. was not as rapid as in the tidal area where port facilities had already been established in colonial times. Alexandria was a bustling seaport and ocean going ships docked as far upstream as Bladensburg on the Anacostia and Georgetown on the Potomac River. Little Falls and Great Falls prevented upstream commerce. It was not until the middle of the nineteenth century that industrial expansion in the upper basin was stimulated by the completion of the much delayed Chesapeake and Ohio Canal to Cumberland by development of railroads in the Valley and by mining of coal resources in the North Branch Potomac basin.

The Potomac River basin has been intimately involved in the history of the nation, the westward expansion, the Civil War, and the reconstruction and development of a central government in Washington which became increasingly involved in domestic and foreign affairs.

B. GEOGRAPHY

The historic source of the Potomac River is at the headwaters of the North Branch in the rugged and forested Allegheny Mountains of the Appalachian chain where the coal mining activity in the basin is concentrated.

The general character of the upper basin does not change appreciably downstream until the Shenandoah Valley is reached. From this area to tidewater, the broader valleys were first used for farming, then towns grew to serve the agricultural community and eventually industry utilized the area's resources as the population increased. The area covered by this report is the Potomac River drainage basin above Great Falls which is approximately 11,500 square miles. The entire basin has a population of 3 million of which 2.5 million are in the Washington Metropolitan Area.

Much of the basin industry is related to agriculture: fruit packing, poultry processing, dairying, and tanning. Natural resources of coal, sand, stone, and forest products are abundant and have been the basis of industrial development in the area.

C. GEOLOGY

The North Branch of the Potomac River has its origin in the Allegheny geophysical province. It passes through the Valley and Ridge province in which major coal and forest product development has occurred, crosses the Great Valley with its extensive agricultural and industrial areas where many of the sediment and pollution problems originate. The Potomac cuts through the Blue Ridge Mountains and the rolling hills of the Piedmont on its way to the Chesapeake Bay.

The non-tidal river drains parts of several states: West Virginia, Pennsylvania, Virginia, Maryland, and a small area of the District of Columbia.

D. HYDROLOGY

Because of the hilly terrain, the soil density, and the rainfall distribution, the Potomac River can be considered a "flashy" stream. Long periods of low flow occur during dry weather in the summer and high flows and occasional floods occur usually during the spring and fall months. Discharges of over 484,000 cfs and less than 800 cfs have been recorded at Washington. The average flow is 11,340 cfs.

CHAPTER V

BACTERIOLOGICAL ANALYSES

A. NORTH BRANCH

Bacteriological populations in the North Branch Potomac River upstream from the Savage River confluence at Bloomington, Maryland are influenced greatly by mine drainage. The extremely low pH levels caused by mine drainage have inhibited the development of all forms of aquatic life.

Water quality surveys of the 50-mile reach between Luke, Maryland and Oldtown, West Virginia were conducted by CTSL on July 28 and August 19, 1969. Graphical presentations of the bacteriological data obtained from these surveys are exhibited in Figures V-1 and V-2.

Both total and fecal coliform concentrations were extremely high (160,000 and 92,000) below the Upper Potomac River Commission's (UPRC) treatment plant (Figure V-1). A reduction in coliform organisms to 3,500 occurred downstream at Keyser, West Virginia. This decrease was followed by a three-fold rise near Cresaptown and a more significant ten-fold rise below the Celanese Fibers Corporation Plant where the total and fecal coliform counts again reached 160,000 and 92,000, respectively. Between the station at River Mile 311 (below Celanese) and the South Branch confluence a sharp dieoff in coliform organisms was noted.

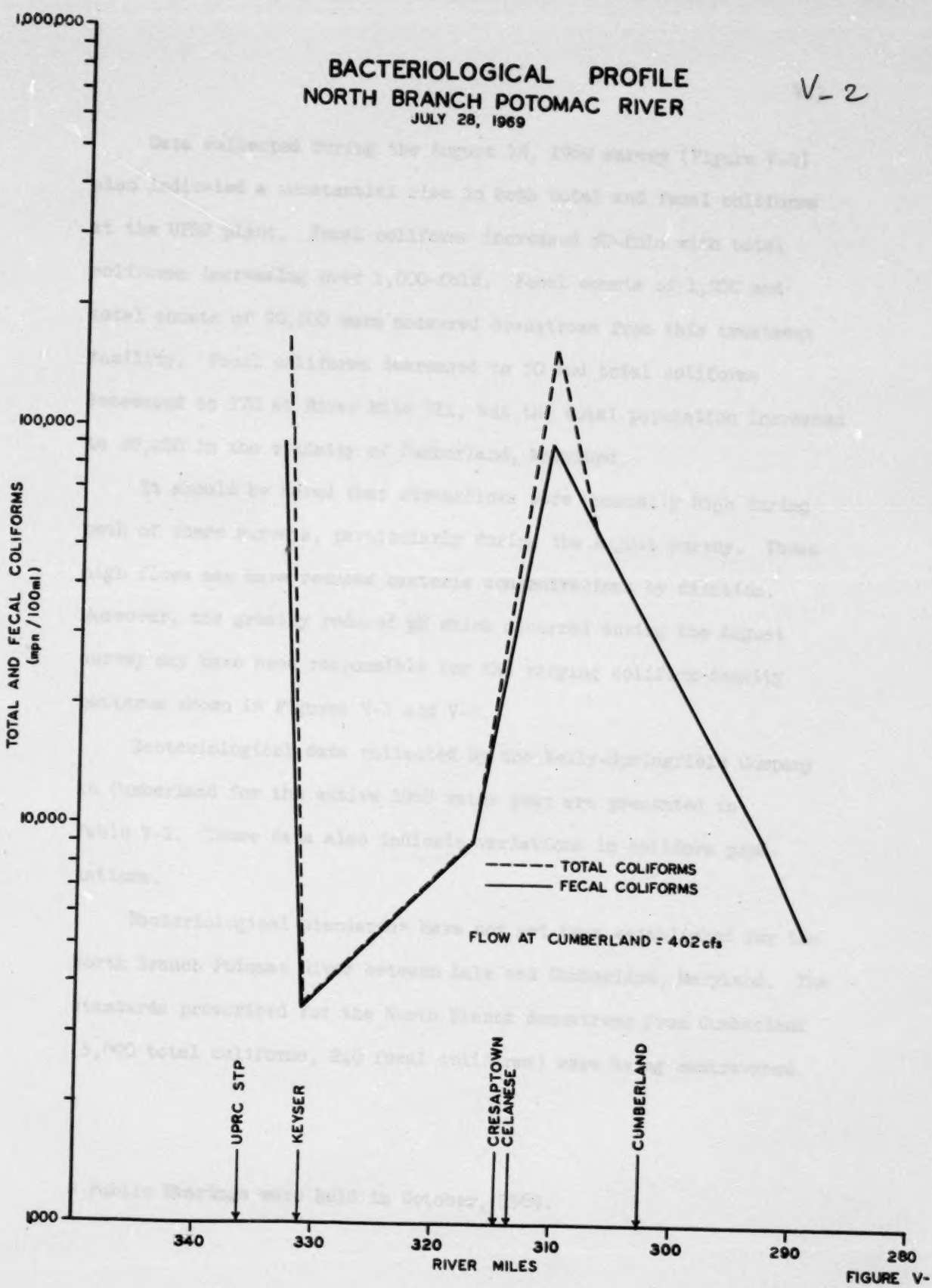

BACTERIOLOGICAL PROFILE
NORTH BRANCH POTOMAC RIVER
JULY 28, 1969
TOTAL AND FECAL COLIFORMS (mpn/100ml)
1,000,000
100,000
10,000
1000
TOTAL COLIFORMS
FECAL COLIFORMS
FLOW AT CUMBERLAND = 402 cfs
UPRC STP
KEYSER
CRESAPTOWN
CELANESE
CUMBERLAND
340
330
320
310
300
290
280
RIVER MILES

FIGURE V-1

Data collected during the August 18, 1969 survey (Figure V-2) also indicated a substantial rise in both total and fecal coliforms at the UPRC plant. Fecal coliforms increased 50-fold with total coliforms increasing over 1,000-fold. Fecal counts of 1,000 and total counts of 90,000 were measured downstream from this treatment facility. Fecal coliforms decreased to 50 and total coliforms decreased to 170 at River Mile 311, but the total population increased to 22,000 in the vicinity of Cumberland, Maryland.

It should be noted that streamflows were unusually high during both of these surveys, particularly during the August survey. These high flows may have reduced bacteria concentrations by dilution. Moreover, the greatly reduced pH which occurred during the August survey may have been responsible for the varying coliform density patterns shown in Figures V-1 and V-2.

Bacteriological data collected by the Kelly-Springfield Company in Cumberland for the entire 1968 water year are presented in Table V-1. These data also indicate variations in coliform populations.

Bacteriological standards* have not yet been established for the North Branch Potomac River between Luke and Cumberland, Maryland. The standards prescribed for the North Branch downstream from Cumberland (5,000 total coliforms, 240 fecal coliforms) were being contravened.

* Public Hearings were held in October, 1969.

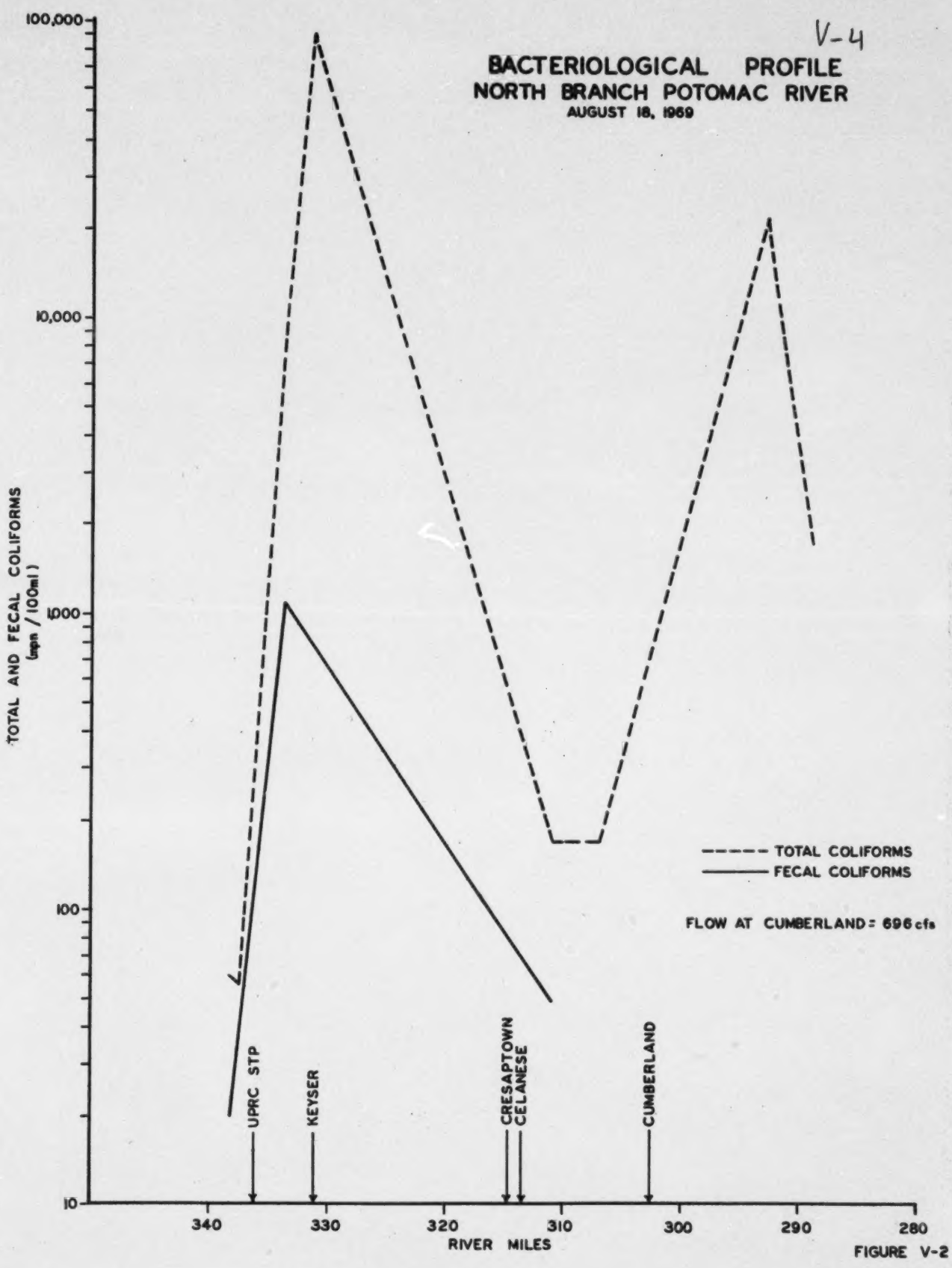

BACTERIOLOGICAL PROFILE
NORTH BRANCH POTOMAC RIVER
AUGUST 18, 1969
TOTAL AND FECAL COLIFORMS (mpn / 100ml)
100,000
10,000
1000
100
10
TOTAL COLIFORMS
FECAL COLIFORMS
FLOW AT CUMBERLAND = 696 cfs
UPRC STP
KEYSER
CRESAPTOWN
CELANESE
CUMBERLAND
340
330
320
310
300
290
280
RIVER MILES

FIGURE V-2

TABLE V-1

BACTERIOLOGICAL DATA

NORTH BRANCH POTOMAC RIVER

AT

CUMBERLAND, MARYLAND

1968-69

Above Plant (308.5)		Below Plant (308.0)	
Month	Total Coliforms (MPN/100ml)	Month	Total Coliforms (MPN/100ml)
October	2,000	October	9,000
November	8,000	November	15,000
December	930	December	930
January	*N/A	January	2,000
March	23,000	March	2,000
April	230	April	430
June	21,000	June	9,000
July	23,000	July	23,000
August	75,000	August	43,000
September	93,000	September	240,000

* Data not available

B. SOUTH BRANCH

Figure V-3 shows extremely high total and fecal coliform densities downstream from Petersburg and Moorefield, West Virginia during the July 1969 survey. Both exceeded 50,000 at River Mile 66.2 and 30,000 three miles below Moorefield (River Mile 53.9). A significant decrease in total and fecal coliforms occurred between stations at River Miles 53.9 and 13.5 even though this stream reach receives primary effluent from the Romney, West Virginia Sewage Treatment Plant.

Sampling data from the August survey (Figure V-4) likewise indicate maximum bacterial populations downstream from Petersburg and Moorefield followed by a sharp die-off further downstream. The total and fecal coliform counts at River Mile 53.9 were both 54,000. The lowest fecal count (370) was recorded at River Mile 13.5.

Bacteriological analyses are conducted routinely by the Romney Waste Treatment Plant. A summary of these data for the past five years of record is shown in Figure V-5. Bacterial concentrations varied considerably over the five year period. Several counts exceeded 20,000. Coliform density peaks frequently occurred during the summer months when stream flows were low and temperatures high. Minimum coliform levels were generally recorded during the winter and spring months.

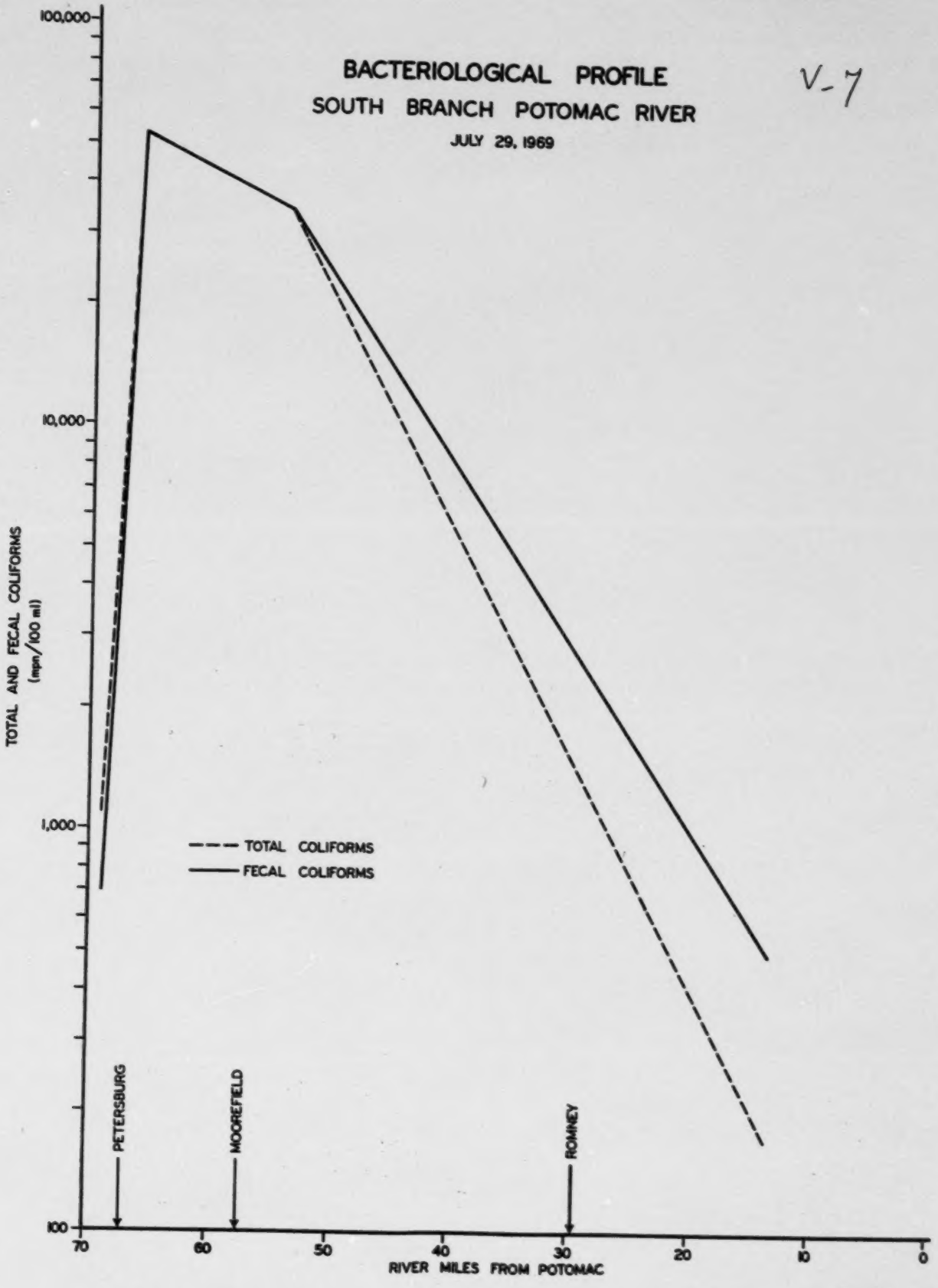

BACTERIOLOGICAL PROFILE
SOUTH BRANCH POTOMAC RIVER
JULY 29, 1969
100,000
10,000
1,000
100
TOTAL AND FECAL COLIFORMS (mpn/100 ml)
TOTAL COLIFORMS
FECAL COLIFORMS
PETERSBURG
MOOREFIELD
ROMNEY
70
60
50
40
30
20
10
0
RIVER MILES FROM POTOMAC

FIGURE V-3

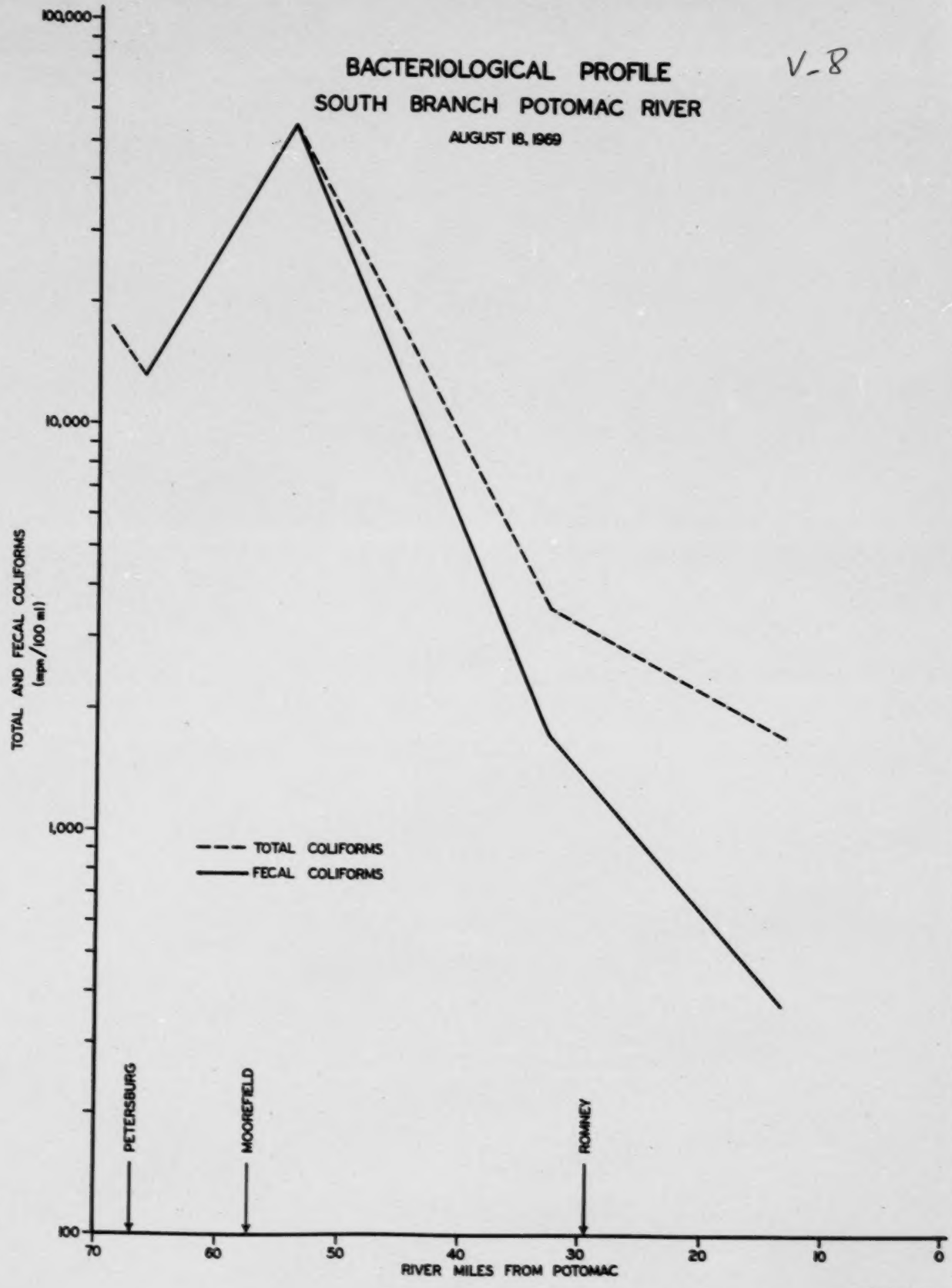

BACTERIOLOGICAL PROFILE
SOUTH BRANCH POTOMAC RIVER
AUGUST 18, 1969
100,000
10,000
1,000
100
TOTAL AND FECAL COLIFORMS (mpn/100 ml)
TOTAL COLIFORMS
FECAL COLIFORMS
PETERSBURG
MOOREFIELD
ROMNEY
70
60
50
40
30
20
10
0
RIVER MILES FROM POTOMAC

FIGURE V-4

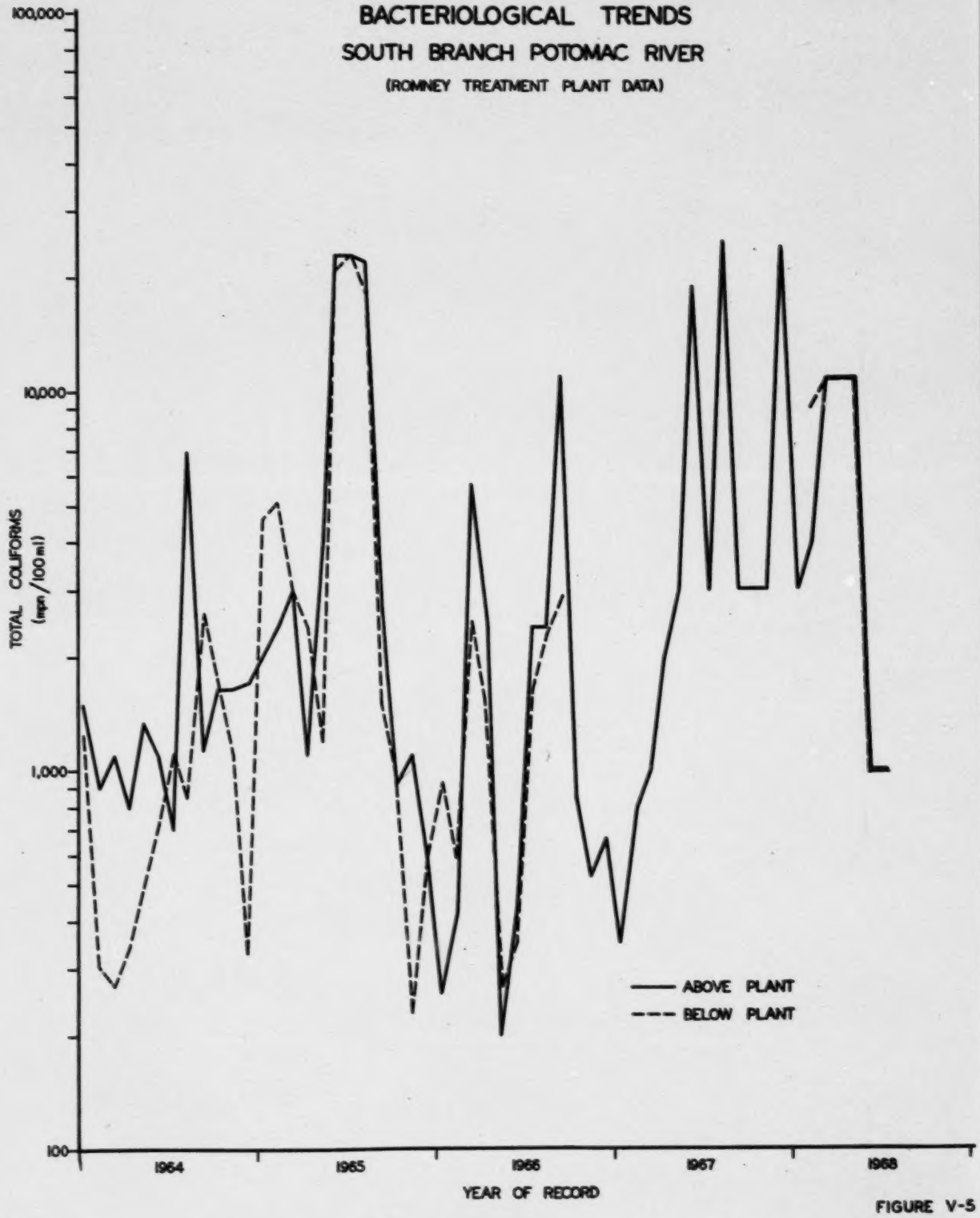

BACTERIOLOGICAL TRENDS
SOUTH BRANCH POTOMAC RIVER
(ROMNEY TREATMENT PLANT DATA)
100,000
10,000
1,000
100
TOTAL COLIFORMS (mpn/100 ml)
1964
1965
1966
1967
1968
YEAR OF RECORD
ABOVE PLANT
BELOW PLANT

FIGURE V-5

C. CONOCOCHEAGUE CREEK

For the July survey, Figure V-6 shows that stations downstream from Chambersburg and Greencastle, Pennsylvania had total and fecal coliform populations in excess of 160,000. Every other station on Conococheague Creek, excepting at River Mile 5.1, had fecal coliform counts in excess of 10,000 and total counts in excess of 50,000. At the Pennsylvania-Maryland State Line, both counts were about 160,000.

Figure V-7 shows a coliform density pattern quite different for the August survey than for the July survey as presented in Figure V-6, a further example of the extreme temporal fluctuations associated with bacteriological populations. Maximum fecal coliform counts (160,000) occurred downstream from Chambersburg with a sharp decrease in these organisms occurring throughout the following 50-mile reach of the stream. Total coliforms varied in a similar manner, except for a large rise (9,200 to 35,000) which occurred downstream from Greencastle near the state line.

The West Branch Conococheague Creek, an intrastate tributary of Conococheague Creek, receives treated wastes from Mercersburg, Pennsylvania. Both total and fecal coliform counts of 92,000 (July 1969) and 5,400 (August 1969) were recorded downstream from Mercersburg.

Neither Pennsylvania's nor Maryland's interstate water quality standards are being met in the Conococheague basin.

BACTERIOLOGICAL PROFILE
CONOCOCHEAGUE CREEK
JULY 28, 1969

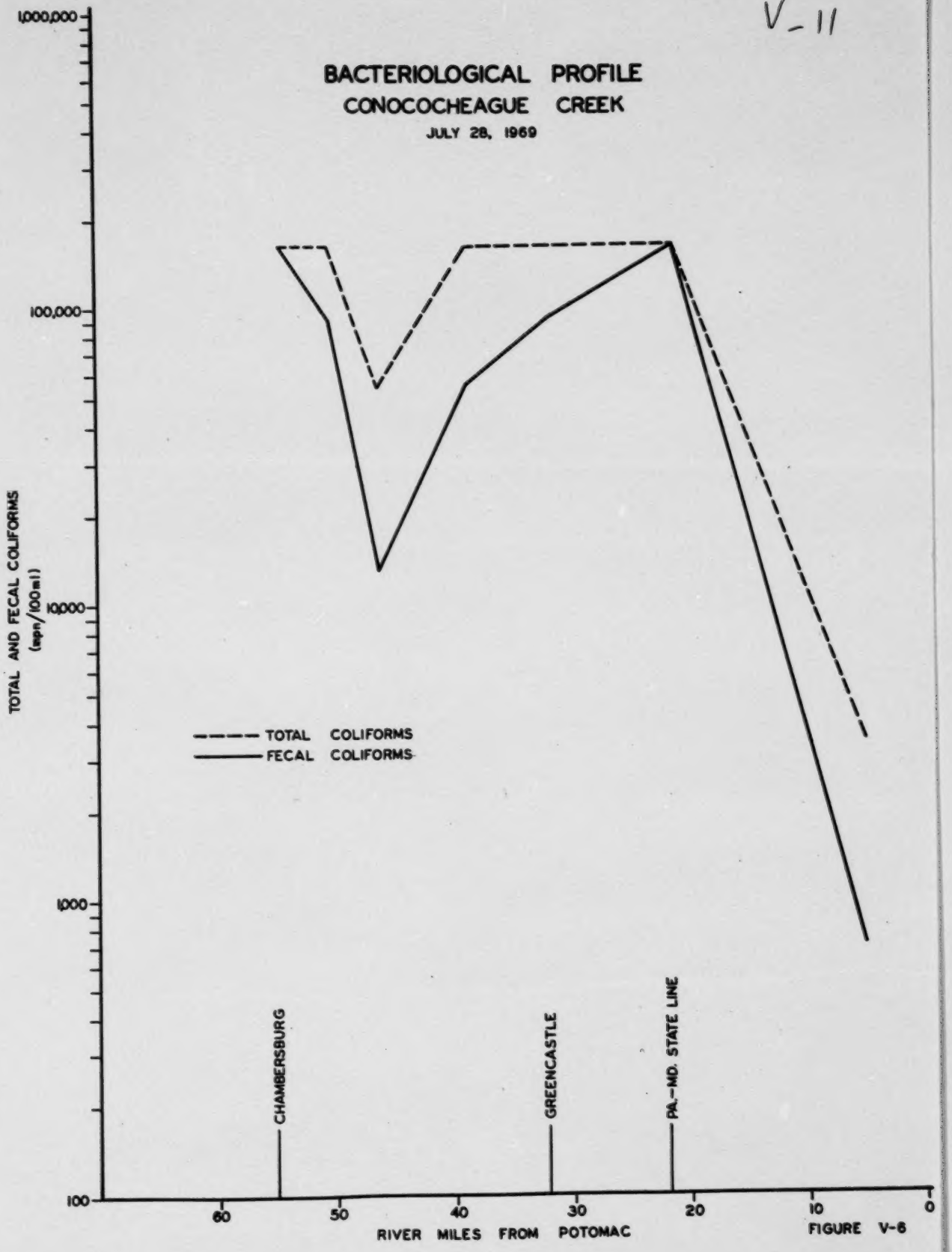


FIGURE V-6

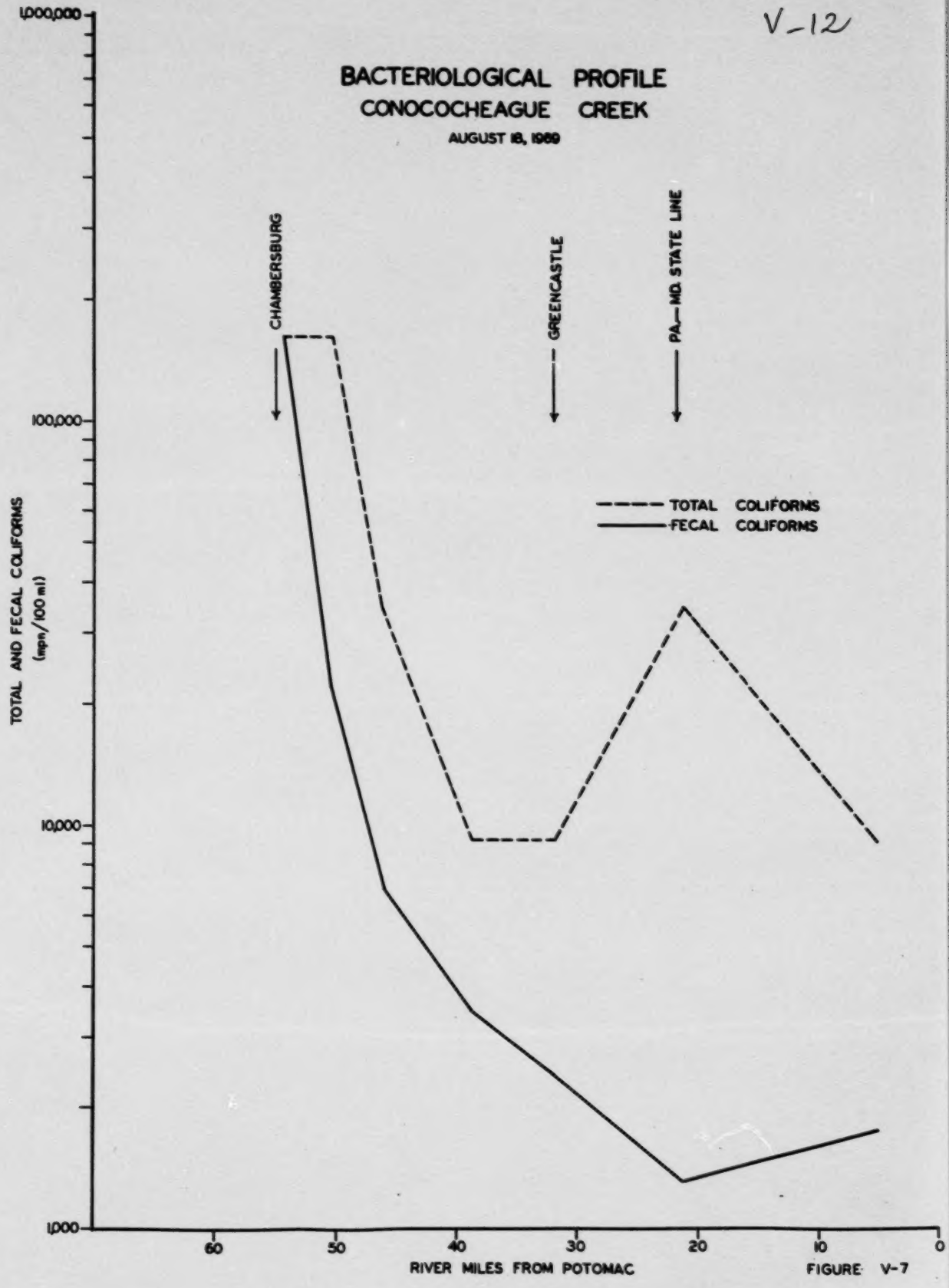

BACTERIOLOGICAL PROFILE
CONOCOCHEAGUE CREEK
AUGUST 18, 1969
CHAMBERSBURG
GREENCASTLE
PA.—MD. STATE LINE
TOTAL COLIFORMS
FECAL COLIFORMS
TOTAL AND FECAL COLIFORMS (mpn/100 ml)
1,000,000
100,000
10,000
1,000
60
50
40
30
20
10
0
RIVER MILES FROM POTOMAC

FIGURE V-7

D. OPEQUON CREEK

While Opequon Creek does not directly receive significant quantities of waste, two of its tributaries, Abrams Creek and Tuscarora Creek, receive large quantities of treated wastes from Winchester, Virginia and Martinsburg, West Virginia. During the August survey, total and fecal coliform counts exceeded 161,000 in Abrams Creek. The influence Abrams Creek exerts on Opequon Creek can readily be seen in Figures V-8 and V-9. Maximum total coliform densities (161,000) and fecal coliform densities (35,000) in Opequon Creek were both recorded in the vicinity of Abrams Creek. Tuscarora Creek, to a lesser degree, also exerts an adverse effect on the bacterial water quality of Opequon Creek. Fecal coliform counts increased seven-fold during the July survey and three-fold during the August survey at the station below Tuscarora Creek.

A bacteriological study of the upper Potomac, including a station on the Opequon Creek below Martinsburg, was conducted by CTSL from July 6 to September 8, 1966. In eighteen samples which were collected during this period, fecal coliforms ranged from 1,300 to 35,000 (See Figure V-18).

The State of Virginia has not assigned bacterial water quality standards to its portion of Opequon Creek. The West Virginia standards were contravened on numerous occasions.

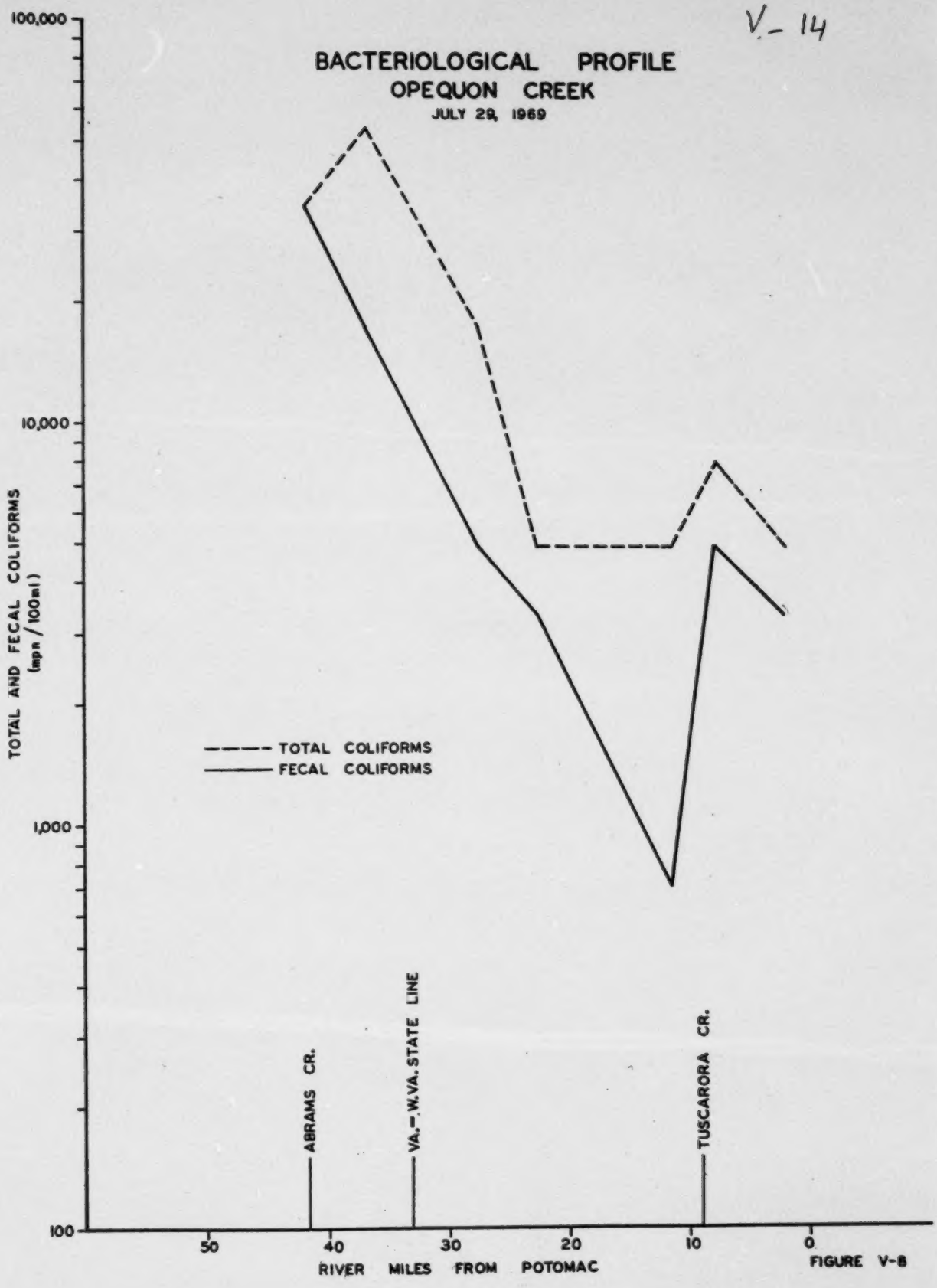

BACTERIOLOGICAL PROFILE
OPEQUON CREEK
JULY 29, 1969
100,000
10,000
1,000
100
TOTAL AND FECAL COLIFORMS (mpn / 100ml)
TOTAL COLIFORMS
FECAL COLIFORMS
ABRAMS CR.
VA.-W.VA. STATE LINE
TUSCARORA CR.
50
40
30
20
10
0
RIVER MILES FROM POTOMAC

FIGURE V-8

BACTERIOLOGICAL PROFILE
OPEQUON CREEK
AUGUST 19, 1969

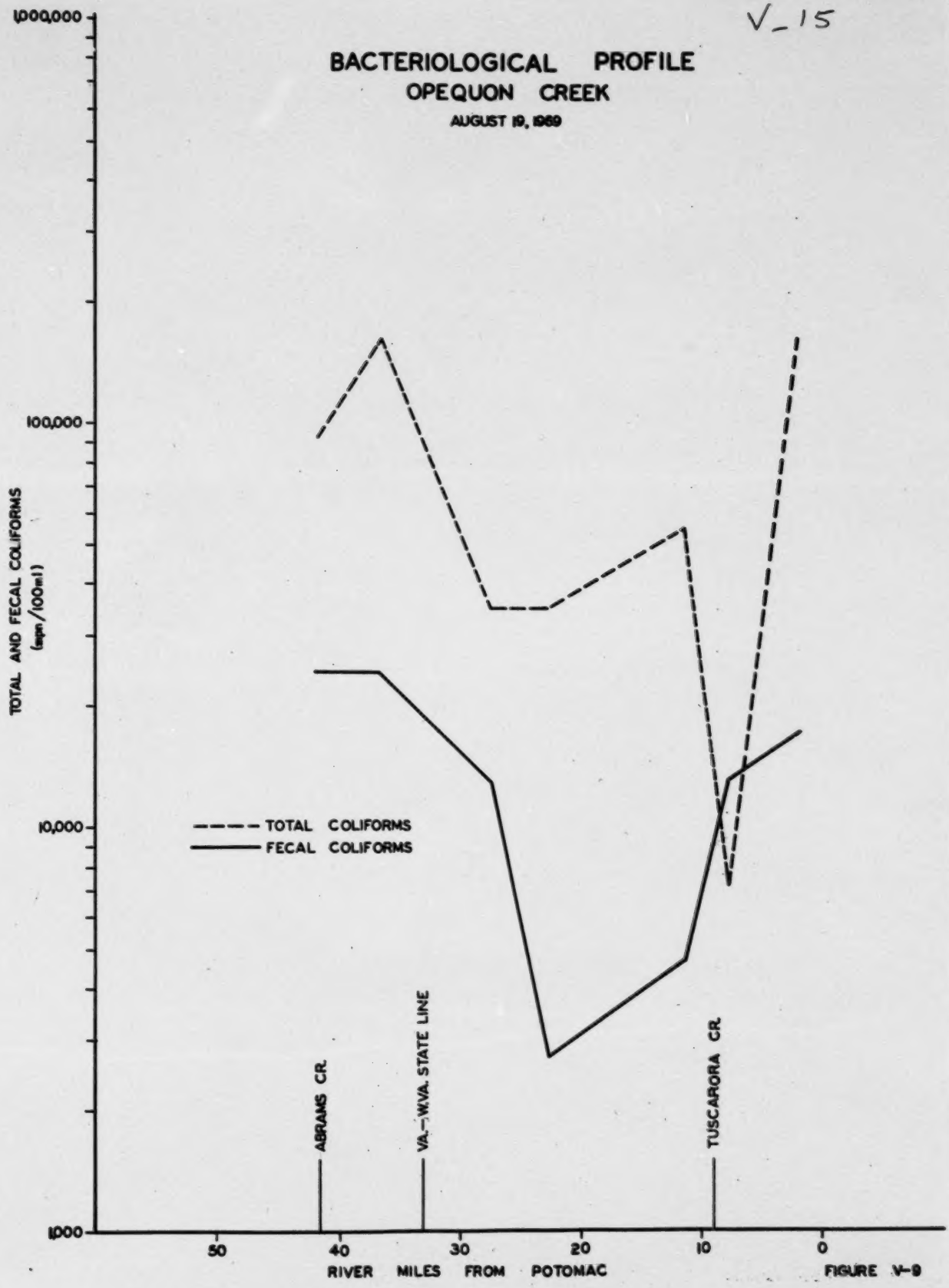


FIGURE V-9

E. ANTIETAM CREEK

The Antietam Creek basin drains portions of Pennsylvania and Maryland. The primary source of organic wastes within Pennsylvania is Waynesboro and Hagerstown is the primary source in Maryland.

Water quality surveys conducted in the Antietam basin by CTSL and the Maryland Department of Water Resources (MDWR) revealed widely variable coliform and fecal coliform populations. During the July 1969 survey, total coliform counts were greater than 161,000 from Hagerstown to River Mile 4.6. Fecal coliform counts throughout this 20 mile stream reach ranged from 161,000 (Hagerstown) to 54,200 (River Mile 13.6). Upstream from Hagerstown, total coliform counts ranged from 17,200 to 161,000 (above and below Waynesboro) and fecal coliforms ranged from 1,400 to 91,800. (See Tables in Appendix)

The August 1969 survey showed a completely different distribution of coliforms. Maximum total and fecal coliform counts greater than 161,000 were recorded from Waynesboro to Hagerstown. Between Hagerstown and the mouth of Antietam Creek both total and fecal coliforms ranged from 4,900 to 91,800.

During July 1969, the U. S. Geological Survey reported fecal coliforms of 10,000 in Antietam Creek near Waynesboro, Pennsylvania and 90 near Sharpsburg, Maryland. Data collected over the past five years by personnel of the Hagerstown Sewage Treatment Plant (below the outfall) show total coliforms ranging from 1 to 3,000.

The bacteriological (total coliform) standard set by Pennsylvania is 2,400*. Recent sampling data indicate that this standard is not being met in Antietam Creek. Maryland's fecal coliform standard (less than 240) is also being contravened.

F. SHENANDOAH RIVER

The Shenandoah basin drains 3,054 square miles in Virginia and West Virginia. Because of its size, more bacteriological data for more stations has been collected from the Shenandoah than from any other stream in the upper Potomac basin.

The most recent intensive bacteriological surveys conducted by CTSL were during July 28-29, 1969 and August 18-19, 1969. Total and fecal coliform populations measured in the South River-South Fork-Shenandoah River during these surveys are shown in Figures V-10 and V-11.

Fecal coliform densities in excess of 20,000 were recorded downstream from the North River confluence, downstream from Elkton, and immediately upstream from Front Royal, Virginia. Moreover, a fecal count in excess of 10,000 was recorded downstream from the North Fork confluence. Total coliforms at each of these locations ranged from about 20,000 to 35,000.

Bacterial pollution in Middle River adversely affects the South Fork. During the July survey, many sampling stations throughout the Middle River sub-basin, including the North River, indicated total and fecal coliform counts of 160,900. Minimum counts of 22,100 total

* For the period 5/15-9/15 only

BACTERIOLOGICAL PROFILE

SOUTH RIVER - SOUTH FORK - SHENANDOAH RIVERS

JULY 28-29, 1969

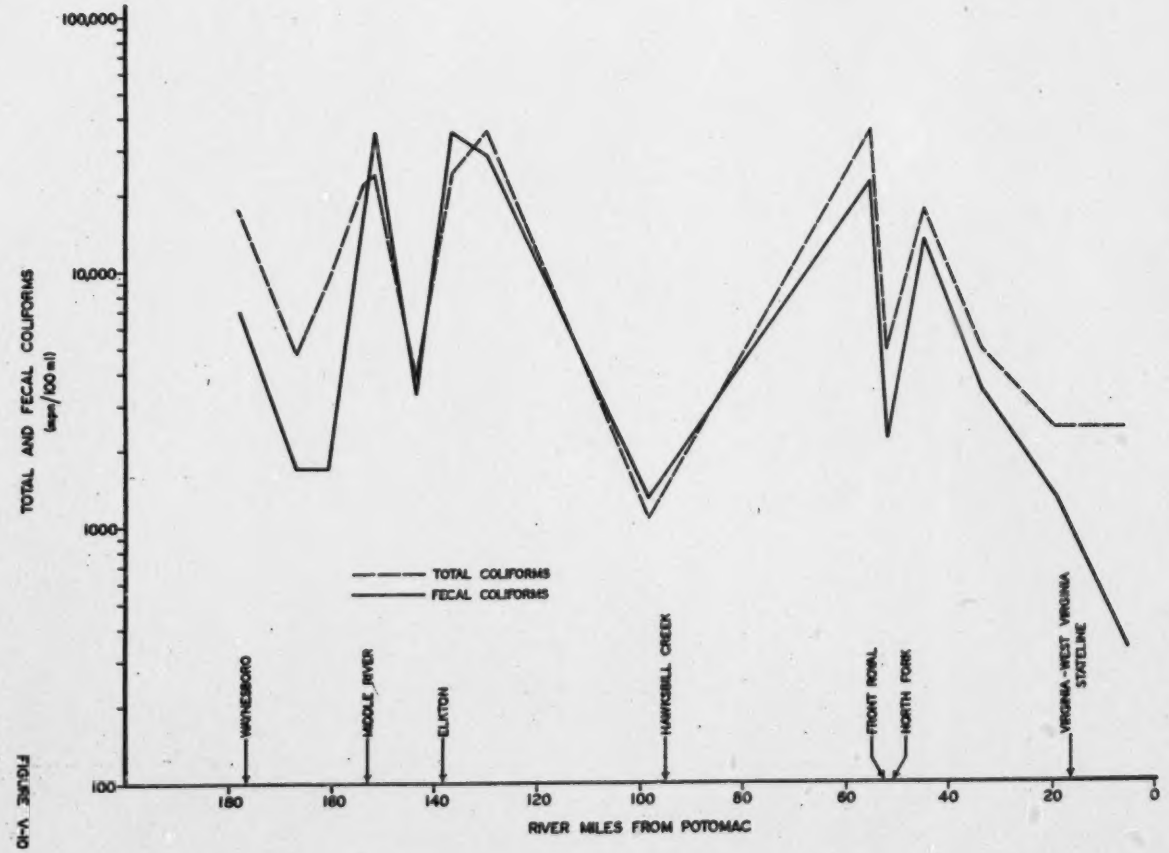


FIGURE V-10

BACTERIOLOGICAL PROFILE

SOUTH RIVER - SOUTH FORK - SHENANDOAH RIVERS

AUGUST 18-19, 1969

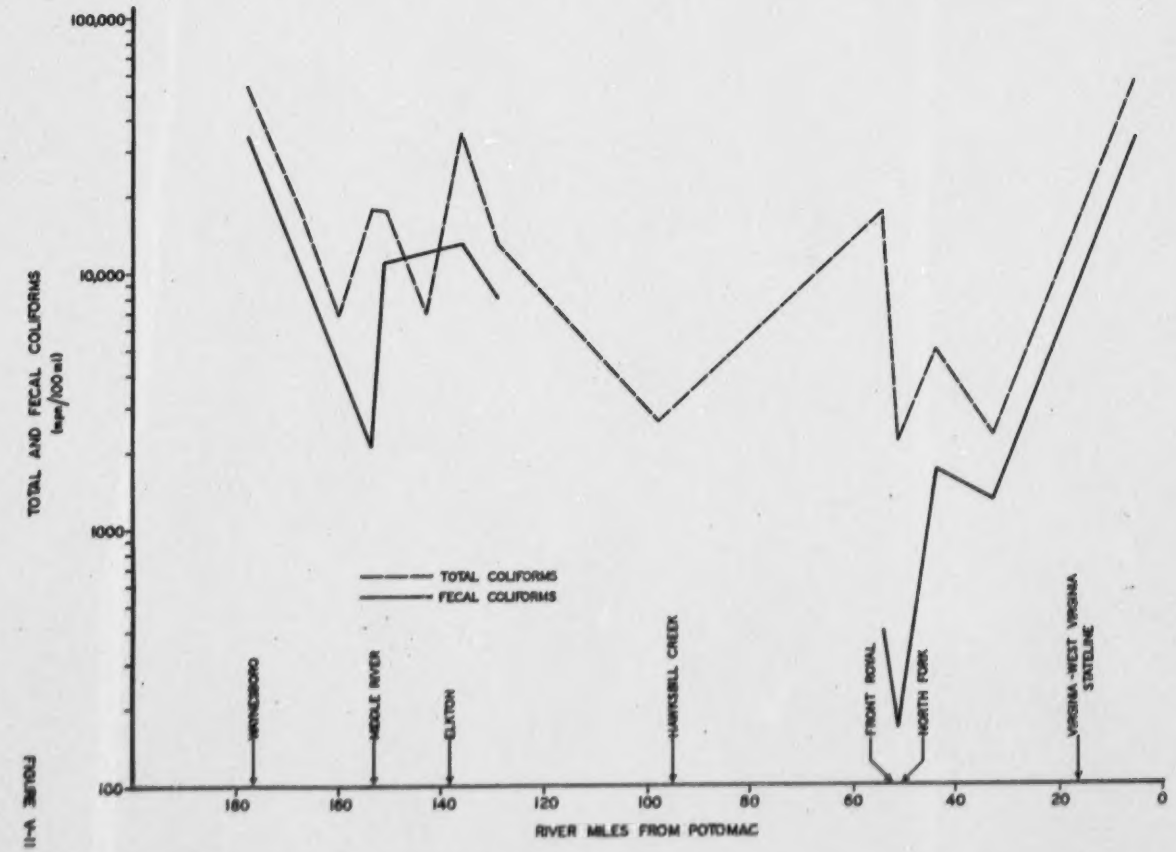


FIGURE V-11

and 34,800 fecal coliforms were recorded in Middle River. The two major pollution sources are Harrisonburg on the North River and Staunton on the Middle River.

The South River-South Fork-Shenandoah River data collected by CTSL during its August survey exhibited a five-fold increase in fecal coliforms at the confluence of the Middle River and a ten-fold increase at the confluence of the North Fork Shenandoah River. Maximum total and fecal coliform densities (54,000 and 34,000) were recorded near Waynesboro and at River Mile 5.0.

During August, the coliform counts were again high in the North and Middle rivers. The North River had total coliform counts of 13,000 and 24,000 and the Middle River had fecal coliform densities as high as 160,900.

Unusually high stream flows occurred during the August 1969 survey. The differences in coliform densities and trends along the main stem Shenandoah River (between River Miles 51 and 5), as shown in Figures V-10 and V-11, may be attributed to this substantially increased stream flow.

The North Fork Shenandoah River was also bacteriologically polluted. During July 1969, total coliforms ranged from 2,600 to 160,900 and fecal coliforms ranged from 3,100 to 91,800. the highest coliform counts occurred in the vicinity of New Market and Edinburg.

A bacteriological study of the entire Shenandoah basin was conducted by CTSL during June 1967 [1]. The data compiled from this study generally agree with the findings presented above. High fecal

coliform counts were recorded in the North Fork Shenandoah at Timberville (91,800), New Market (9,180), and near Quicksburg (5,420). Corresponding total coliform counts at these stations ranged from 54,200 to 160,900. Maximum fecal counts in the South Fork (490-5,400) occurred downstream from Elkton. Relatively high concentrations (180-2,100) were also recorded in the South Fork downstream from the Middle River confluence. North River exhibited a maximum fecal coliform count of 4,600 and a maximum total coliform count of 160,900. Fecal coliform counts in Middle River ranged from 20 to 790 and counts in the main stem Shenandoah River were generally less than 20.

The temporal variation in coliform organisms in the Shenandoah basin is quite significant. A special study was conducted by CTSL from July to September 1966 to determine the extent of temporal variation. Based upon 13 samples, the South Fork exhibited a fecal coliform range of 20 to 16,000; the range in the North Fork was 1,720 to 24,000. Fecal coliform counts in the Shenandoah River at Harper's Ferry are presented in Figure V-12. Extreme temporal fluctuations can readily be seen at this station despite the fact that stream flows were relatively constant (260 to 674 cfs) over the sampling period.

Extensive sampling data collected over the past three years indicate that bacteriological water quality standards, where established in the Shenandoah basin, were generally not being met under any flow conditions.

BACTERIOLOGICAL PROFILE
SHENANDOAH RIVER at HARPERS FERRY
JULY-SEPTEMBER, 1966

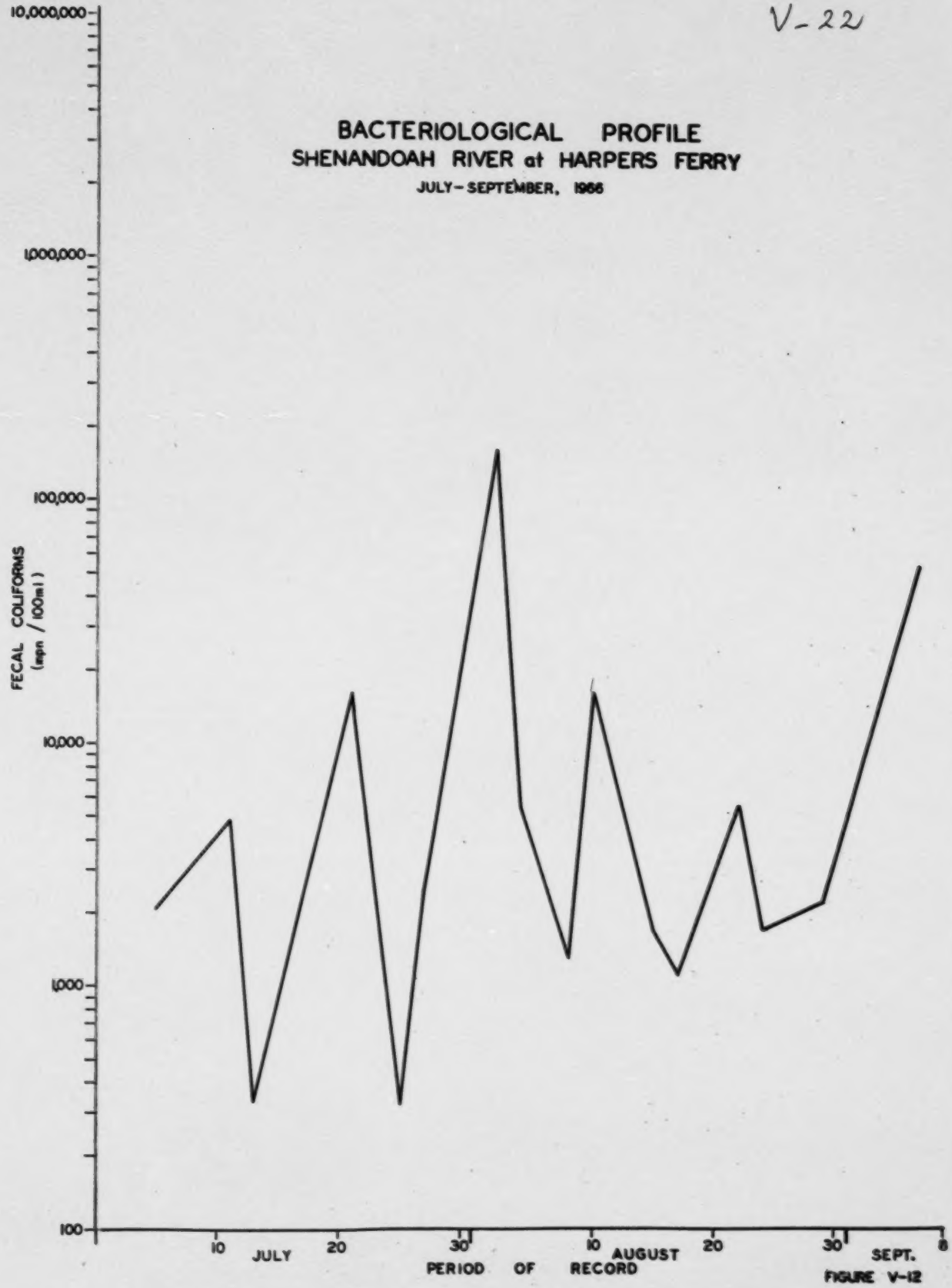


FIGURE V-12

G. MONOCACY RIVER

The total and fecal coliform populations in the Monocacy River basin during July and August 1969 were considerably greater than populations measured in other areas of the upper Potomac basin. Of the 13 stations sampled, ten stations produced total and fecal coliform counts in excess of 160,000 during the July study and five stations produced like values during the August study.

Although the Monocacy basin receives wastewater discharges from many sources, the largest of which is Frederick, Maryland, the persistence of high bacterial levels indicates that rural and urban runoff also play a significant role in affecting water quality. During both surveys stream flow was abnormally high which may have resulted in a "flushing" of coliforms from the predominately agricultural watershed and a "scouring" of sludge deposits along the stream bed.

The Maryland Department of Water Resources investigated the bacteriological water quality of the Monocacy River from March to December 1966 [2]. It was concluded from this study that domestic animals, primarily cattle, contribute most of the coliform organisms upstream from Frederick. Maximum total coliform counts in the upper Monocacy exceeded 2,000,000 with median counts over 9,000. The maximum values occurred during high stream flow periods.

Immediately below the city of Frederick, maximum total coliforms during the MDWR survey exceeded 2,000,000 and median counts were 235,000. Relatively high coliform populations (greater than 100,000) persisted downstream to the Potomac confluence. Maximum coliforms

in the lower Monocacy generally occurred when stream flows were very low, an indication that surface runoff is a less significant contributor of coliforms than it was in the upper reaches.

Long-term coliform data collected from the Monocacy River (River Mile 2.0) by the D. C. Department of Health, are shown in Figure V-13. This figure shows that the coliform counts generally increased over the past five years of record but with considerable temporal variation. Maximum counts of 250,000 were recorded in December 1967 and July 1968, but high counts were also recorded during other months.

Bacteriological data collected in the Monocacy by various agencies indicate that the water quality standards were being contravened throughout the year.

H. MAIN STEM

Survey data from the main stem Potomac River are presented for July and August 1969 in Figures V-14 and V-15. Distribution of bacteria in the Potomac was similar in both the July and August surveys, but the August survey generally yielded higher bacterial counts despite comparable flows. Relatively high total coliform counts (54,000) and fecal coliform counts (3,300) were recorded at Paw Paw, Maryland, a station strongly influenced by the water quality in the North Branch Potomac. The highest counts were at Great Falls where total and fecal coliform counts were 160,000 and 10,900, respectively.

During the July and August surveys a sharp increase in bacterial densities occurred between stations at River Mile 183.7 (Shepherdstown)

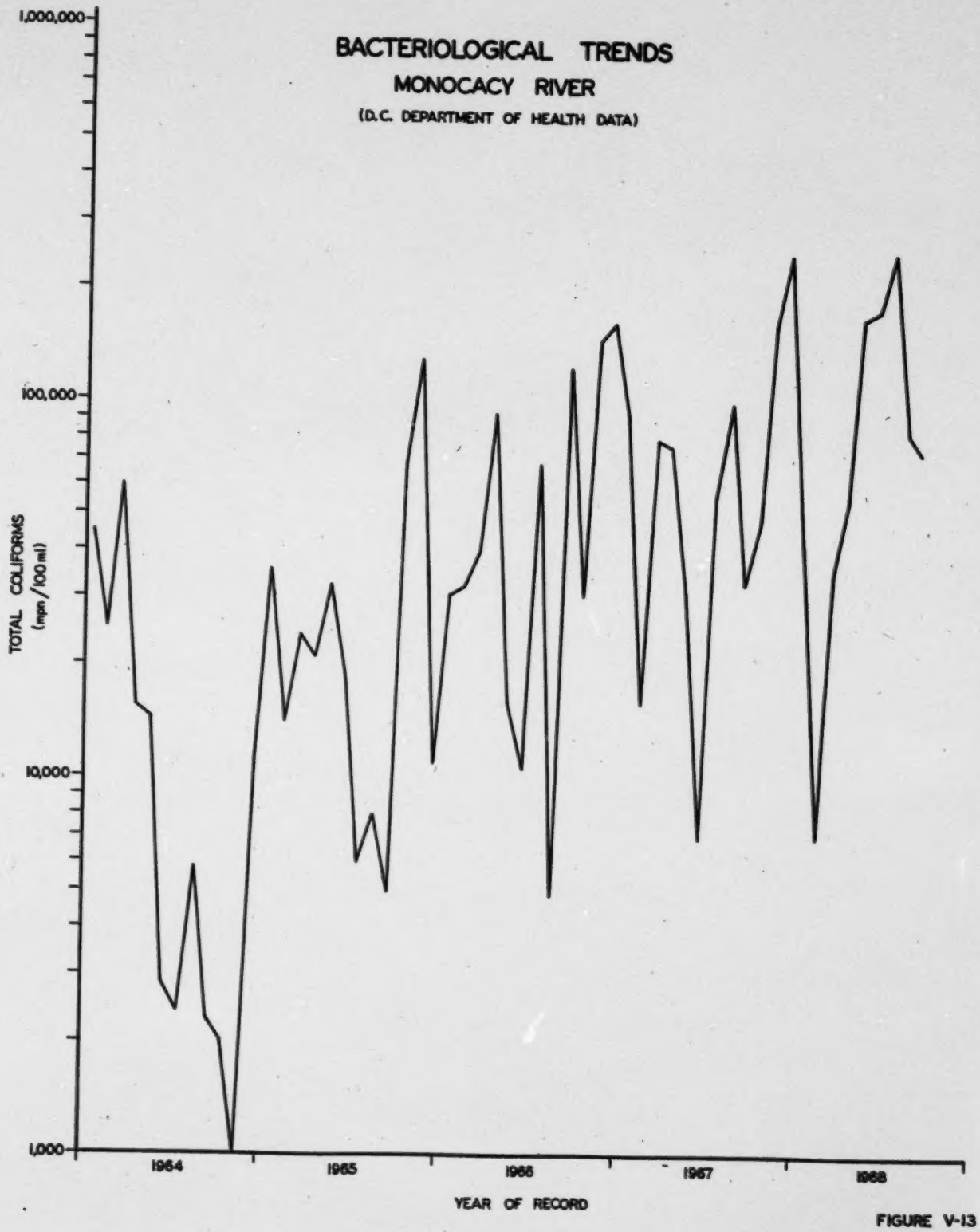

BACTERIOLOGICAL TRENDS
MONOCACY RIVER
(D.C. DEPARTMENT OF HEALTH DATA)
1,000,000
100,000
10,000
1,000
TOTAL COLIFORMS (mpn/100 ml)
1964
1965
1966
1967
1968
YEAR OF RECORD

FIGURE V-13

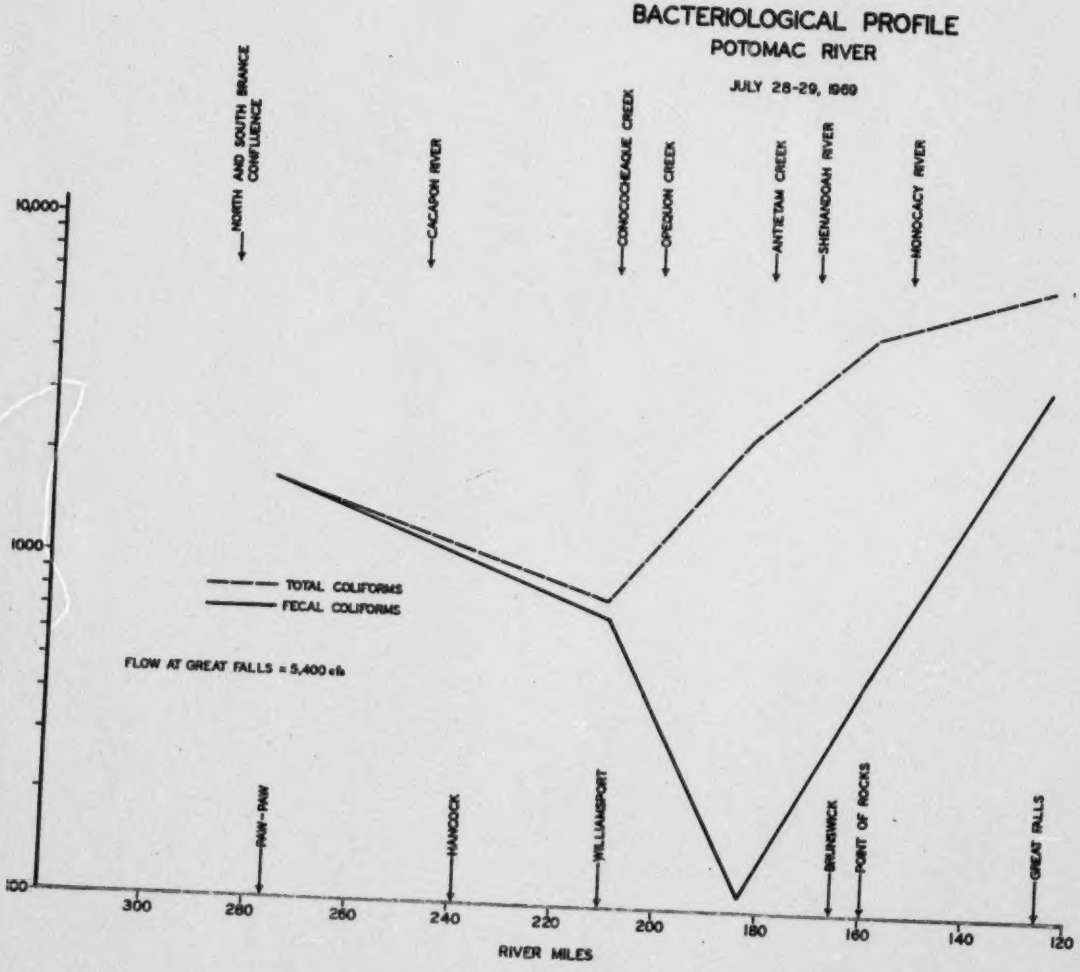

BACTERIOLOGICAL PROFILE
POTOMAC RIVER
JULY 28-29, 1969
NORTH AND SOUTH BRANCH CONFLUENCE
CACAPON RIVER
CONOCOCHEAGUE CREEK
OPEQUON CREEK
ANTIETAM CREEK
SHENANDOAH RIVER
MONOCACY RIVER
TOTAL AND FECAL COLIFORMS (mpn/100 ml)
10,000
1000
100
TOTAL COLIFORMS
FECAL COLIFORMS
FLOW AT GREAT FALLS = 5,400 cfs
PAW-PAW
HANCOCK
WILLIAMSPORT
BRUNSWICK
POINT OF ROCKS
GREAT FALLS
300
280
260
240
220
200
180
160
140
120
RIVER MILES

FIGURE V-14

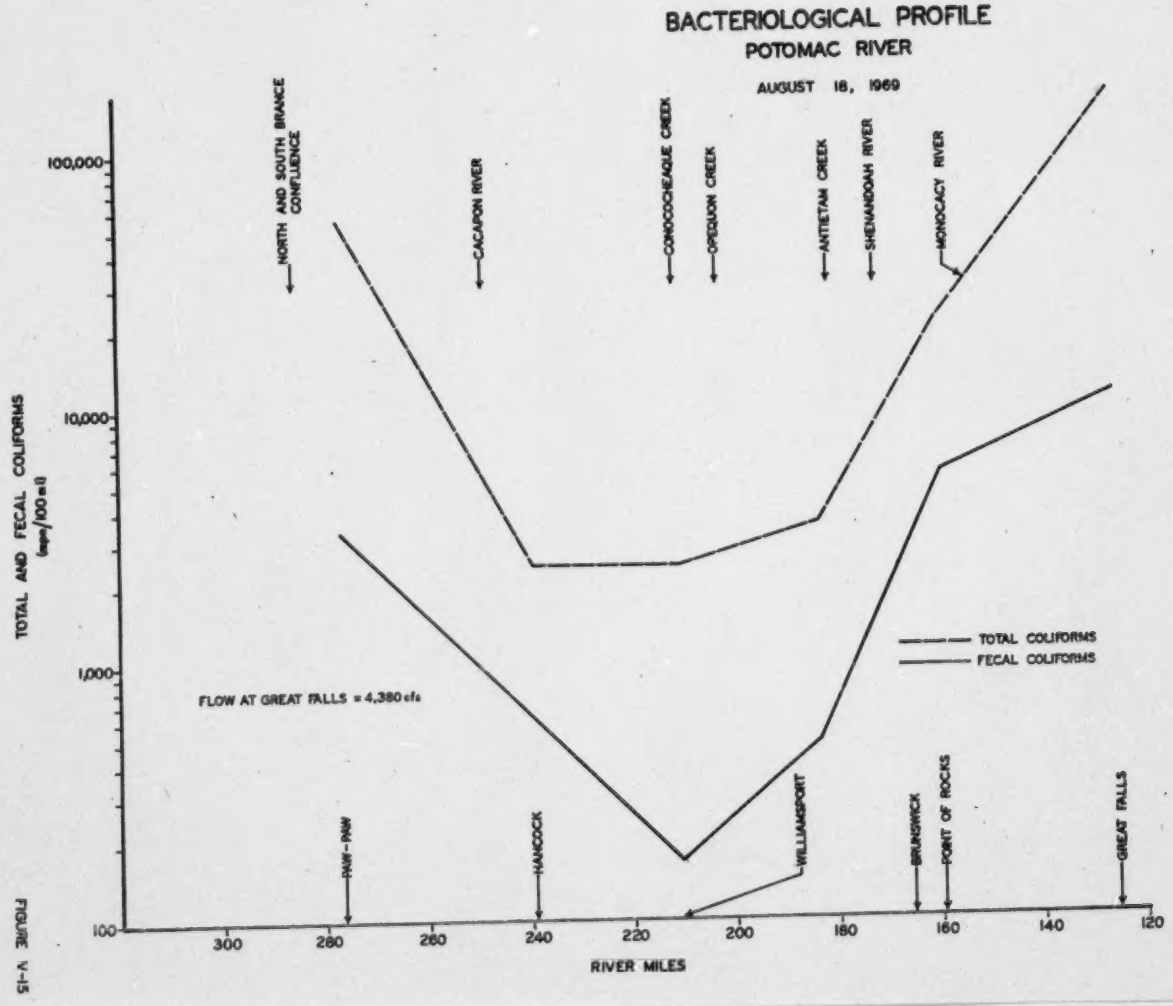

BACTERIOLOGICAL PROFILE
POTOMAC RIVER
AUGUST 18, 1969
TOTAL AND FECAL COLIFORMS (mpn/100 ml)
100,000
10,000
1,000
100
NORTH AND SOUTH BRANCH CONFLUENCE
CACAPON RIVER
CONOCOCHEAGUE CREEK
OPEQUON CREEK
ANTIETAM CREEK
SHENANDOAH RIVER
MONOCACY RIVER
TOTAL COLIFORMS
FECAL COLIFORMS
FLOW AT GREAT FALLS = 4,380 cfs
PAW-PAW
HANCOCK
WILLIAMSPORT
BRUNSWICK
POINT OF ROCKS
GREAT FALLS
300
280
260
240
220
200
180
160
140
120
RIVER MILES

FIGURE V-15

and River Mile 125.7 (Great Falls). This increase may be the result of bacterial pollution in Antietam Creek, the Shenandoah River, and the Monocacy River. The wastewater discharges directly to the Potomac River appear to have a lesser effect on its bacterial content than the major tributaries do.

The bacteriological data for five years of record, collected at Great Falls by the water supply facility at Dalecarlia, is shown in Figure V-16. A sharp rise over those five years is evident. Fecal coliform counts are also shown in Figure V-16 for almost two years of record (1967-68). During this period the temporal variation of fecal coliforms closely paralleled the variation in total coliform organisms. Maximum fecal counts (75,000-85,000) were measured at Great Falls during July and August 1968 when total counts exceeded 140,000.

Similar long-term bacteriological data for the Potomac River at Point of Rocks are shown in Figure V-17. When these data are compared with the data presented in Figure V-13, it appears that the influence of the Monocacy River on the bacterial water quality at Great Falls results in higher bacterial counts than those found in the Potomac at Point of Rocks.

The Maryland water quality standards of the Potomac River were being contravened. Throughout the main stem of the Potomac River, populations ranging from 1,000 to 10,000 were frequently recorded.

BACTERIOLOGICAL TRENDS
POTOMAC RIVER at GREAT FALLS
(DALECARLIA DATA)

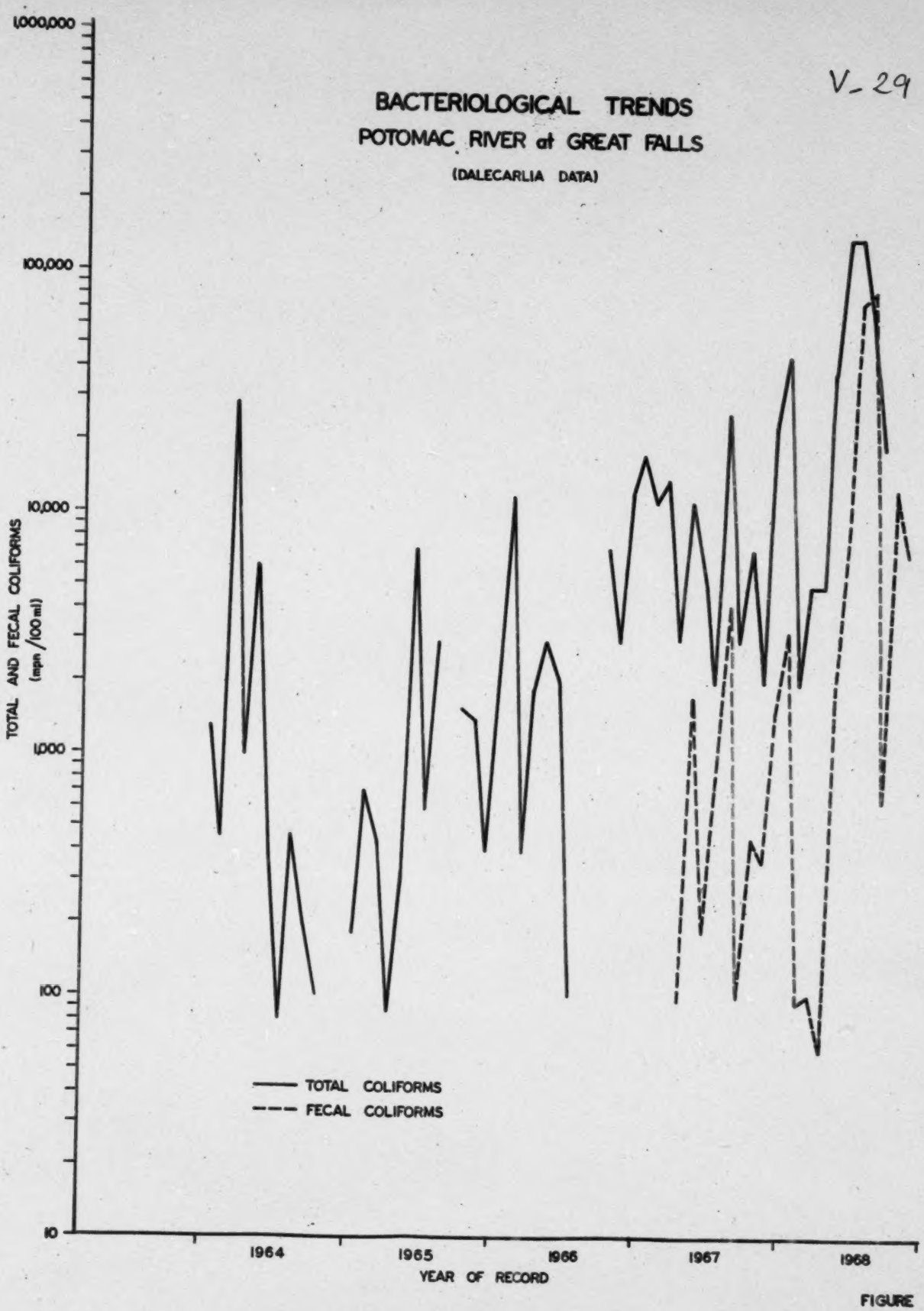


FIGURE V-16

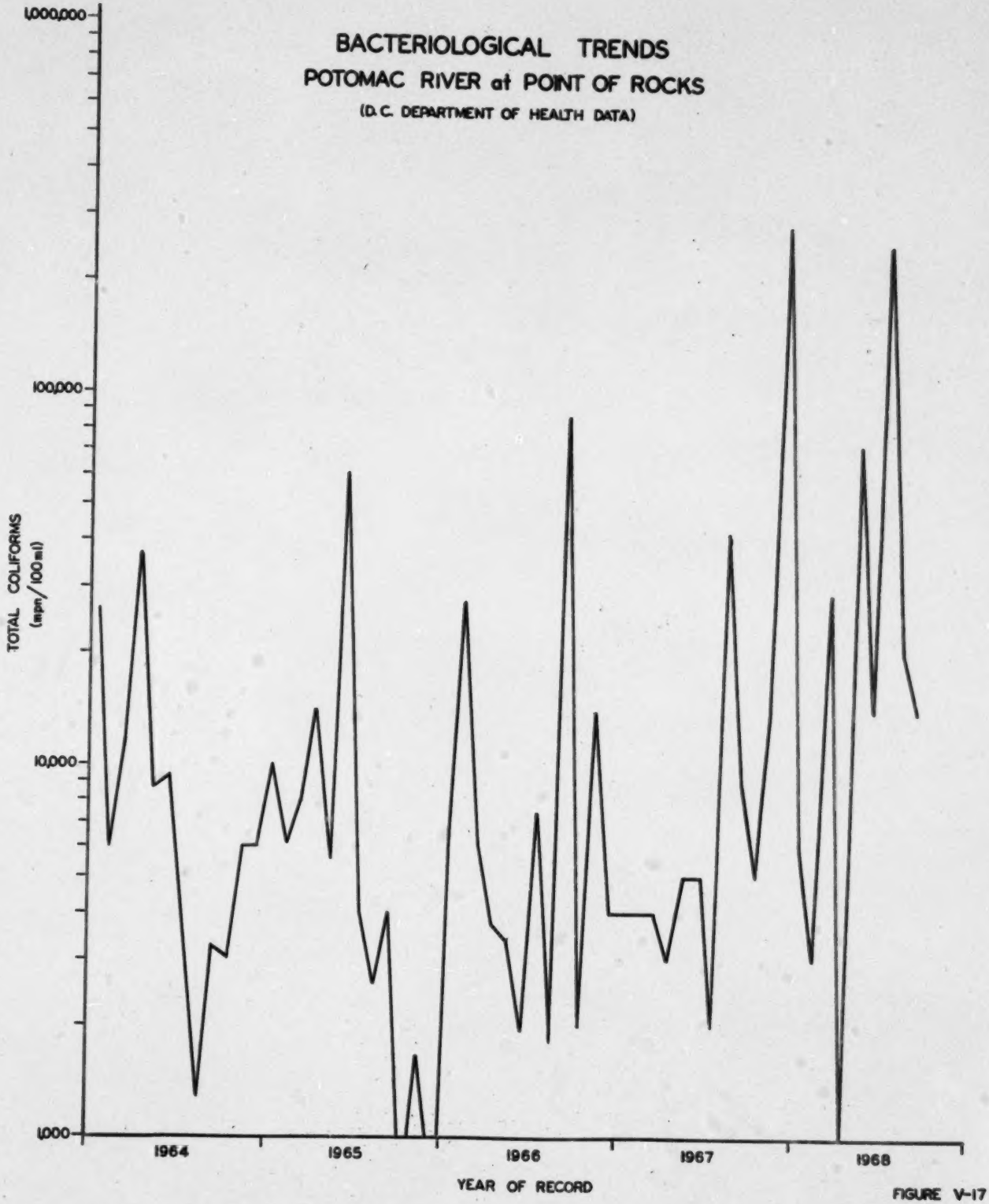

BACTERIOLOGICAL TRENDS
POTOMAC RIVER at POINT OF ROCKS
(D.C. DEPARTMENT OF HEALTH DATA)
1,000,000
100,000
10,000
1,000
TOTAL COLIFORMS (mpn/100ml)
1964
1965
1966
1967
1968
YEAR OF RECORD

FIGURE V-17

I. DISCUSSION

Based upon the foregoing discussions, it is apparent that coliform populations fluctuate greatly both temporally and spatially. It is also apparent that bacterial water quality standards are being contravened throughout the upper Potomac basin during all flow periods.

Despite all of the bacteriological data, there are two important questions which cannot be answered with any degree of certainty: (1) the effect, if any, that stream flow and rainfall have on the bacterial content of a stream, and (2) the significance of agricultural, urban, and other land runoff as a contributor of coliform bacteria. In order to adequately assess bacteriological water quality in the upper Potomac, these questions must be answered.

Some insight into the second question can be obtained by examining Figure V-18, wherein fecal coliform densities are plotted for two watersheds that are geographically similar but with different land use. Figure V-18 shows that the urbanized and agricultural Opequon basin produced fecal coliforms an order of magnitude greater than the heavily forested Cacapon basin.

In areas where consistently high fecal coliform counts are encountered, a detailed sanitary survey should be conducted to ascertain whether human wastes or other sources are the dominant cause of bacterial contamination.

To minimize bacterial pollution of the receiving waters, chlorination facilities are generally provided at all sewage treatment plants. The effective operation of these facilities is the responsibility of the various state health departments.

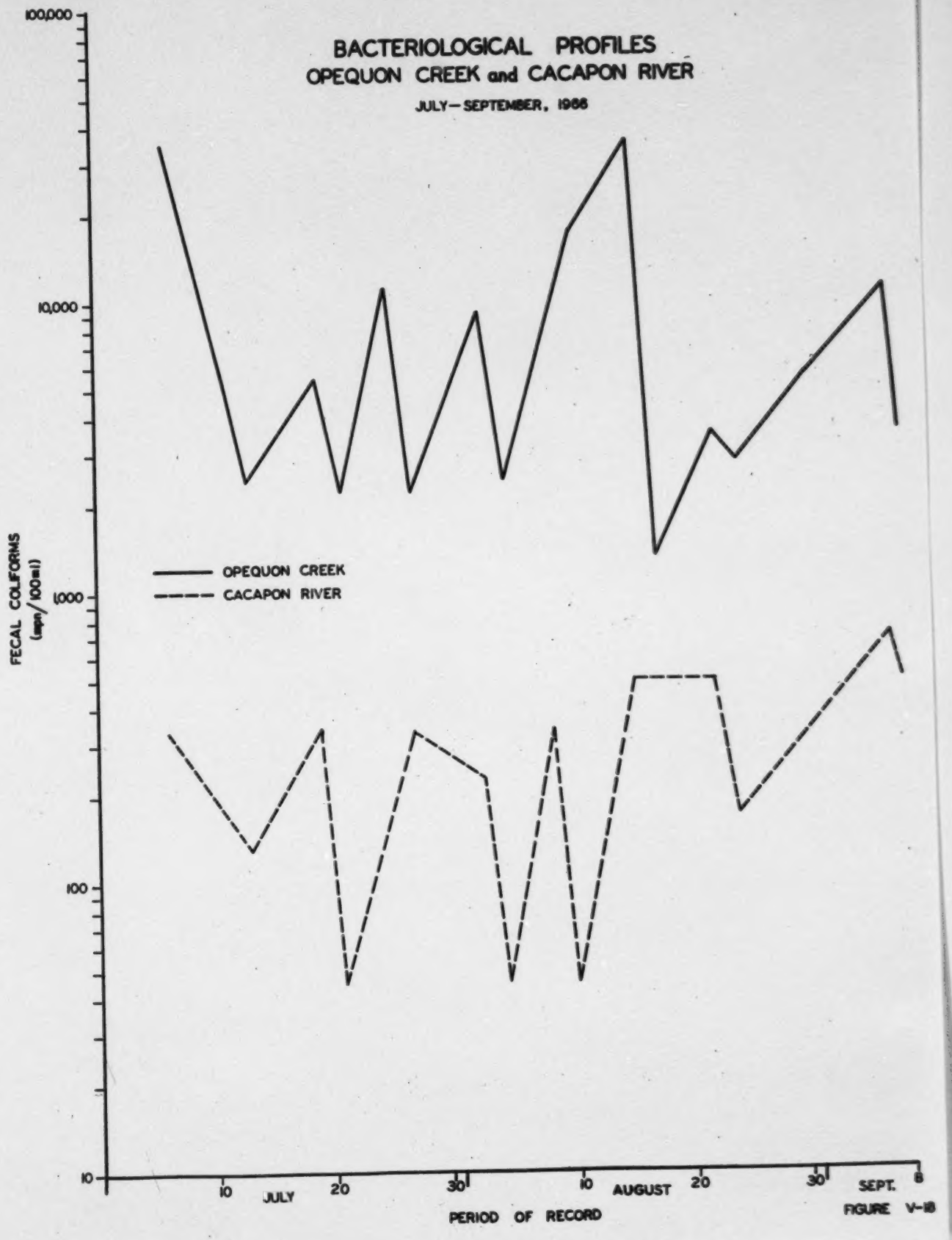

BACTERIOLOGICAL PROFILES
OPEQUON CREEK and CACAPON RIVER
JULY–SEPTEMBER, 1966
100,000
10,000
1,000
100
10
FECAL COLIFORMS (mpn/100ml)
OPEQUON CREEK
CACAPON RIVER
10
JULY
20
30
10
AUGUST
20
30
SEPT.
8
PERIOD OF RECORD

FIGURE V-18

CHAPTER VI

DISSOLVED OXYGEN AND BIOCHEMICAL OXYGEN DEMAND

A. NORTH BRANCH

The major sources of wastewater discharge in the North Branch sub-basin are listed below:

Facility	Wastewater flow (mgd)	Discharge BOD (lbs/day)
West Virginia Pulp and Paper Co.*	11.0	16,000
Upper Potomac River Commission	21.0**	5,300
Keyser, West Virginia	0.6	400
Celanese Fibers Company	3.0	25,000
Cumberland, Maryland	5.2	6,930

As a result of loadings from West Virginia Pulp and Paper Company and the Upper Potomac River Commission facility, the dissolved oxygen (DO) from Luke, Maryland to Keyser, West Virginia was often below 1.0 mg/l (Figure VI-1). The Maryland water quality standard for this reach is 4.0 mg/l.

As a result of the BOD loadings from Celanese Fibers Company, the DO of the North Branch from Amcelle to Cumberland was often below 1.0 mg/l in the summer months. Hydrogen sulfide gas was detected in the small impoundment at Cumberland indicating septic conditions.

* Now Westvaco

** About 20.0 mgd is from the West Virginia Pulp and Paper Company

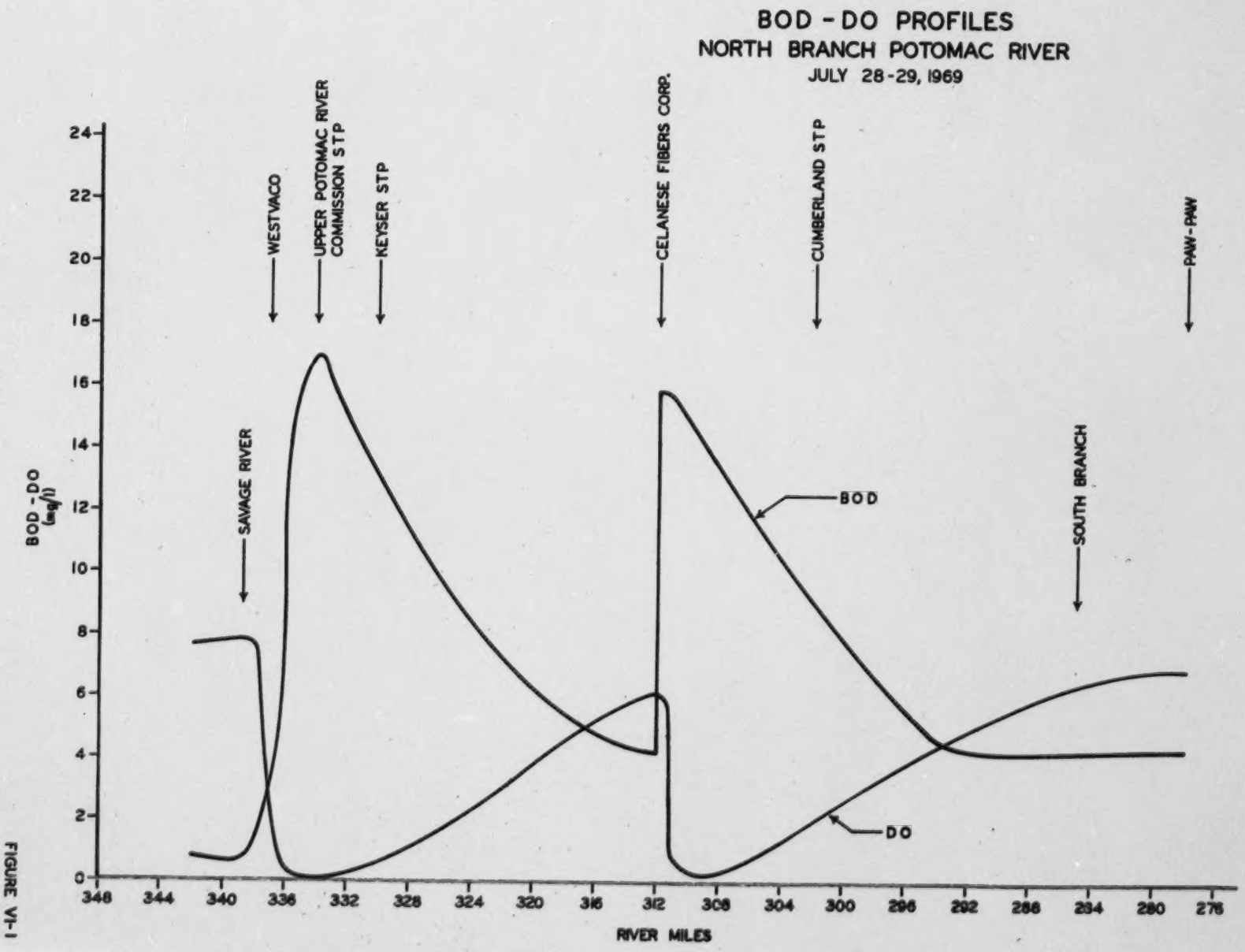

BOD - DO PROFILES
NORTH BRANCH POTOMAC RIVER
JULY 28-29, 1969
BOD - DO (mg/l)
24
22
20
18
16
14
12
10
8
6
4
2
0
WESTVACO
UPPER POTOMAC RIVER COMMISSION STP
KEYSER STP
CELANESE FIBERS CORP.
CUMBERLAND STP
PAW-PAW
SAVAGE RIVER
SOUTH BRANCH
BOD
DO
348
344
340
336
332
328
324
320
316
312
308
304
300
296
292
288
284
280
276
RIVER MILES

FIGURE VI-1

During an intensive survey by CTSL in August of 1966, DO concentrations of less than 2.0 mg/l were observed downstream to Spring Gap, a distance of about ten miles from Cumberland, Maryland. Low DO concentrations with high BOD levels were also observed in this same reach in July 1969 (Figure VI-1). The DO standard for this reach is 5.0 mg/l.

B. SOUTH BRANCH

Compared to the North Branch, the South Branch of the Potomac River receives relatively small volumes of wastewater as tabulated for the major facilities below:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
Petersburg, W. Va.	0.27	75
Loewengart & Company	0.40	790
Moorefield, W. Va.	0.04	240
Rockingham Poultry	0.15	670
Romney, W. Va.	0.34	200
Berkeley Springs, W. Va.	0.17	280

Although localized pollution has been observed, the DO concentrations in South Branch were usually above 6.0 mg/l. The standard for DO is 5.0 mg/l for this reach of the Potomac.

C. CONOCOCHEAGUE CREEK

The major wastewater discharges on the Conococheague watershed are presented below:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
Chambersburg, Pa.	1.80	730
H. J. Heinz Co., Pa.	0.43	290
Loewengart & Co., Pa.	0.18	590
Mercersburg, Pa.	0.22	60
Greencastle, Pa.	0.13	50
W. D. Byron Co.	0.37	1,390

Water quality data for the July and August 1969 survey indicate DO levels greater than 5.8 mg/l for all the sampling stations. While the BOD concentrations varied from about 2.0 to over 7.0 mg/l, the assimilative capacity of the Conococheague appears adequate to maintain DO levels over 5.0 mg/l. A Pennsylvania water quality network station near Worleytown established in 1962 also confirms high DO concentrations in the Conococheague.

D. OPEQUON CREEK

The major Opequon Creek sub-basin wastewater discharges containing organic matter are listed below:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
Winchester, Va.	2.40	460
O'Sullivan Rubber Co., Va.	2.10	unknown
Clearbrook Woolen Mills, Va.	0.20	unknown
Minn. Mining & Mfg. Co., W. Va.	0.62	420
Musselman-Pet Milk Co., W. Va.	0.30	1,500
Martinsburg, W. Va.	1.50	950
Corning Glass Works, W. Va.	0.53	35

The BOD concentrations in Abrams and Tuscarora creeks for the 1969 surveys were 5.0 mg/l and the BOD at the other stations ranged between 2.2 and 5.0 mg/l. At all stations the DO was above 5.0 mg/l. (See Appendix A for data listing.)

High nutrient levels were also observed in the Abrams and Tuscarora creeks and this is discussed in Chapter X. In general, streams in this watershed are in compliance with the water quality standards.

E. ANTIETAM CREEK

The major wastewater discharges in the Antietam Creek sub-basin are:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
Waynesboro, Pa.	1.96	285
Ft. Ritchie, Md.	0.14	5
Hagerstown, Md.	5.58	6,900
Fairchild-Hiller Corp., Md.	0.18	45
Halfway, Md.	0.25	260
Sharpsburg, Md.	0.10	110

The major source of BOD is from the Hagerstown sewage treatment facility, which causes a significant DO depression during low flow conditions (Figure VI-2). The rapid DO recovery indicates high reaeration rates in Antietam Creek.

Diurnal observations during a cooperative study by MDWR and CTSL demonstrated the typical daylight-dark diurnal fluctuations of DO and CO_2 associated with aquatic plant growths [2]. In the Antietam watershed, most of the growths were rooted aquatic plants and phytoplankton.

F. SHENANDOAH RIVER

The Shenandoah sub-basin is the largest tributary of the Potomac River.

BOD-DO PROFILES*

ANTIETAM CREEK

DIURNAL STUDY

JUNE 26-28, 1967

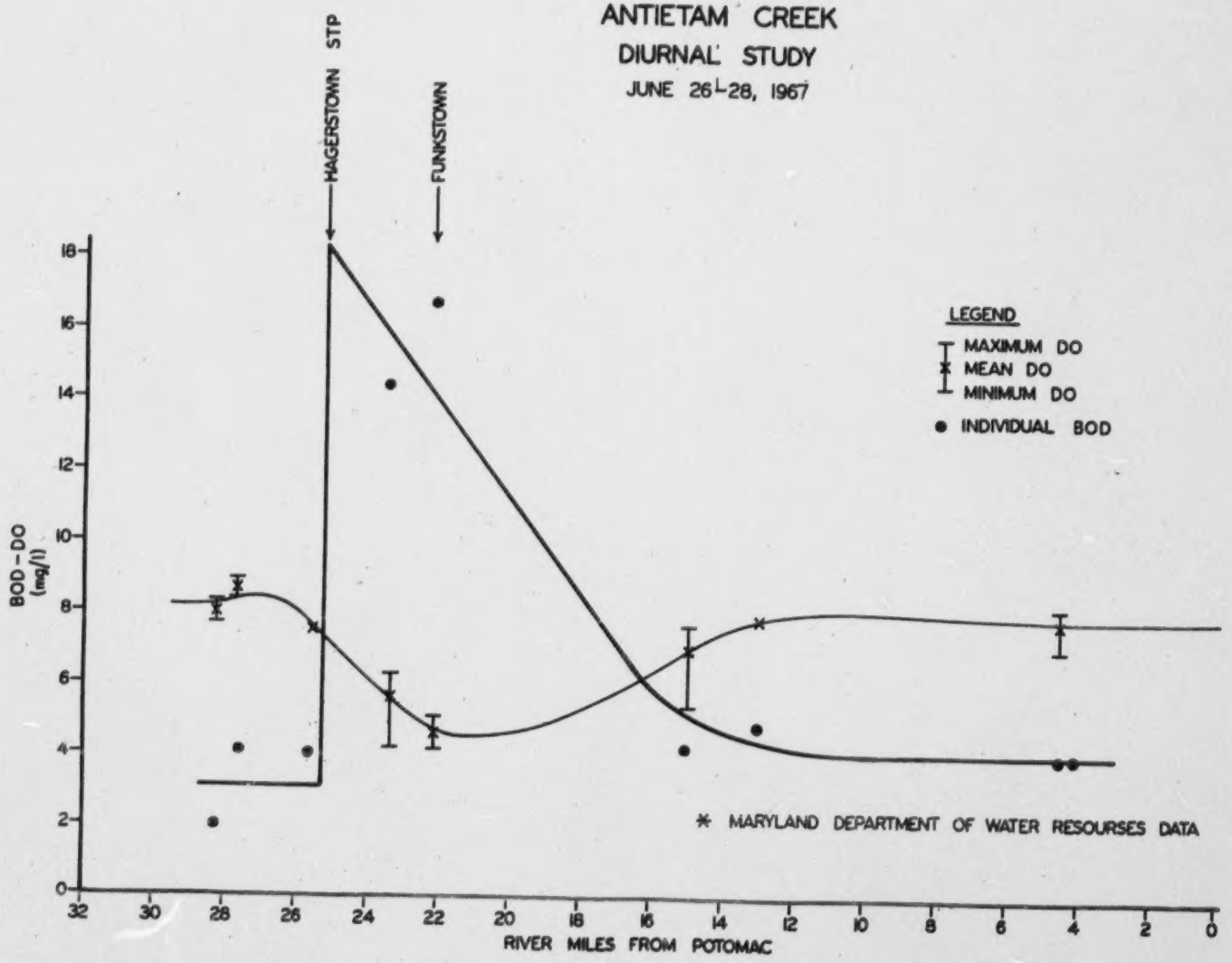


FIGURE VI-2

1. North Fork

In the North Fork Shenandoah watershed, which is mainly forested, the major wastewater discharges are as follows:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
Broadway, Va.	0.13	35
Rockingham Poultry Corp.	0.50	650
Shenandoah Valley Packers	0.20	290
New Market, Va.	0.35	355
Caroline Foods	0.17	unknown
Mt. Jackson, Va.	0.11	130
Shenandoah Mfg. Co.	0.30	170
Blue Ridge Poultry & Egg Co.	0.07	750
Woodstock, Va.	0.35	90
Strasburg, Va.	0.30	100

During the June 1967 intensive survey by CTSL, low BOD concentrations, with corresponding high DO levels, were observed except near Timberville and on Smith Creek near New Market where low DO values were measured. Similar observations were made during the July and August 1969 surveys. The DO depressions occurred downstream from the several wastewater discharges.

2. South Fork

The upper South Fork Shenandoah is composed of three tributaries--North, Middle, and South rivers. The major wastewater discharges in the tributaries and the mainstream are identified separately below:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
a. North River		
Va. Valley Processes, Inc.	0.10	1,000
Bridgewater, Va.	0.26	430
Dayton, Va.	0.16	270
Harrisonburg, Va.	2.25	1,100
b. Middle River		
Verona San. Dist.	0.13	35
Staunton, Va.	1.50	410
Western State Hospital	0.25	70
c. South River		
Crompton Shenandoah Co.	0.89	920
E. I. DuPont Co.	11.00	1,800
Waynesboro, Va.	2.30	645
d. Main Stem South Fork		
Merck & Co.	7.70	3,500
Elkton, Va.	0.25	250
Rockingham Poultry	0.07	300
Moyer Brothers	0.10	1,700
Va. Oak Tannery Co.	0.43	500
Luray, Va.	0.28	420
Amer. Viscose Corp.	8.64	9,350
Front Royal, Va.	1.20	1,000

There are five reaches of the South Fork in which water quality degradation occurs as a result of wastewater discharges. These are (1) South River below Waynesboro; (2) Grassy Run below Harrisonburg; (3) South Fork below Elkton; (4) Hawksbill Creek below Luray and (5) Main Stem at Front Royal. Of the five areas, the most critical in terms of DO is the South River (Figure VI-3). Grassy Creek, which receives wastes from the Harrisonburg area, also had DO ranging from

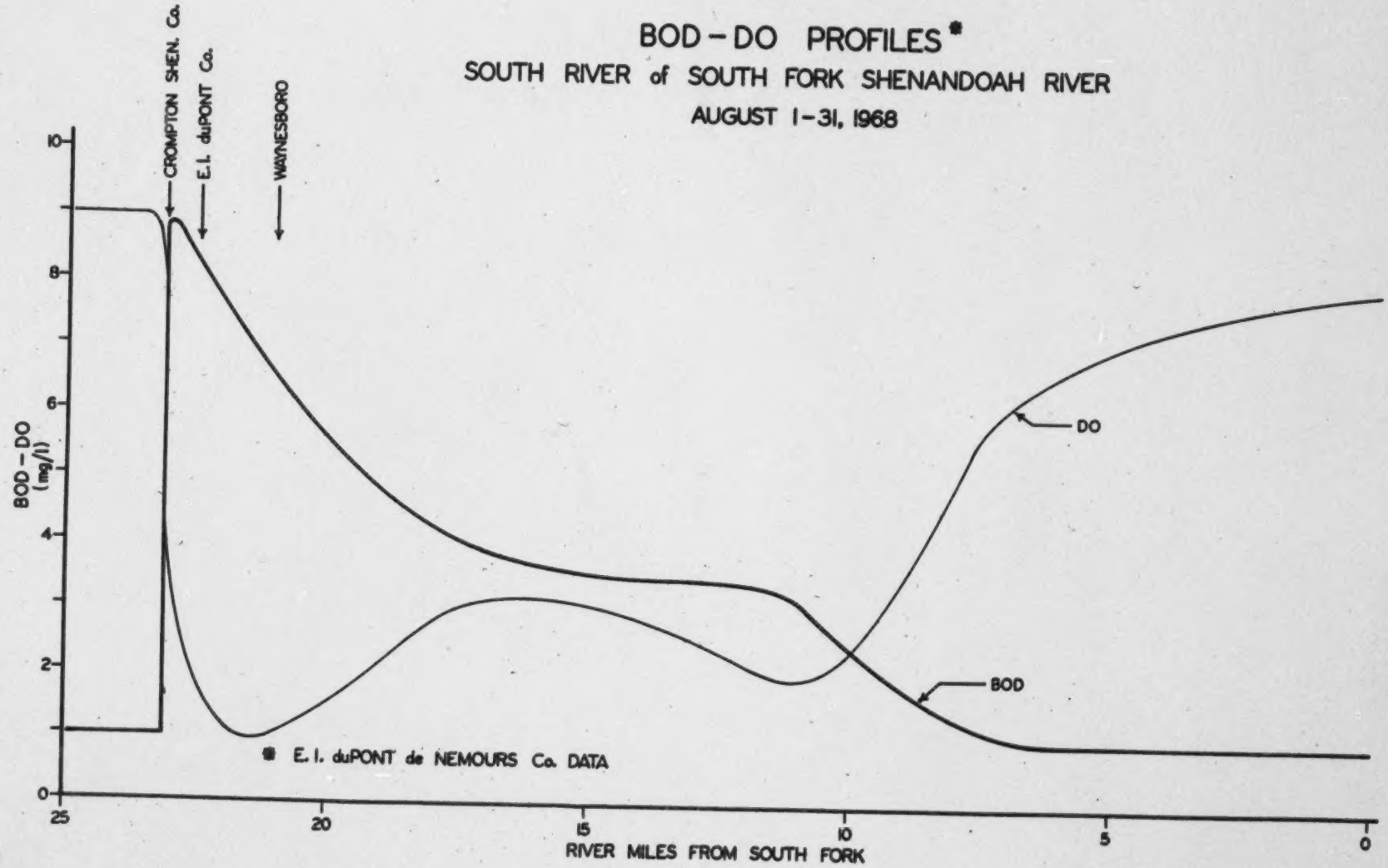

BOD - DO PROFILES *
SOUTH RIVER of SOUTH FORK SHENANDOAH RIVER
AUGUST 1-31, 1968
CROMPTON SHEN. Co.
E.I. duPONT Co.
WAYNESBORO
BOD - DO (mg/l)
10
8
6
4
2
0
DO
BOD
* E. I. duPONT de NEMOURS Co. DATA
25
20
15
10
5
0
RIVER MILES FROM SOUTH FORK

FIGURE VI-3

1.7 to 3.2 mg/l with a BOD level greater than 13 mg/l during an intensive survey in June of 1967.

On the main stem of the South Fork below Elkton, BOD concentrations ranging from 5.7 to over 15.0 mg/l were measured in June of 1967. This varying BOD loading resulted in a DO variation from 4.5 to 15.8 mg/l.

Data from the July 1969 survey indicated that the water quality in Hawksbill Creek is degraded as a result of industrial wastes. More data are required to evaluate the extent of the degradation.

Discharges in the Front Royal area have the greatest adverse effect on the main stem of the Shenandoah. This is presented in the following section.

3. Main Stem of Shenandoah River

The main stem receives the residual wastewater discharges from the Front Royal area and from the major sources discharging into tributaries of the main stem as listed below:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
Berryville, Va.	0.25	104
Charlestown, W. Va.	0.38	443
Halltown Paperboard Co.	1.00	4,200

During the June 1967 survey, the DO in the main stem between Front Royal and Harper's Ferry varied from 5.2 mg/l at night to 12.9 mg/l in the daytime. The BOD during the survey also varied diurnally from 5.2 to 11.3 mg/l. For the July and August 1969

survey, somewhat lower DO concentrations were observed, ranging from 5.1 to 6.7 mg/l.

The mean monthly data for the nutrient water quality network station at Berryville, West Virginia (Figure VI-4) indicate that the stream is in compliance with the water quality standard at this point.

G. MONOCACY RIVER

The major wastewater discharges in the Monocacy River watershed are listed below:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
Gettysburg, Pa.	0.90	375
Littlestown, Pa.	0.26	130
Emmitsburg, Md.	0.21	55
Taneytown, Md.	0.19	120
Westminster, Md.	0.80	410
Union Bridge, Md.	0.10	30
Camp Detrick, Md.	0.80	10
Frederick, Md.	4.88	9,660

The largest source of pollution is the Frederick waste treatment facility. The wide range of BOD in the Frederick facility's effluent, caused by varying industrial wastewater loadings into the treatment plant and extensive algal and rooted aquatic growth in the river itself, is shown in the diurnal DO profile (Figure VI-5).

During low flow conditions, the DO in the main stem downstream from the Frederick facility was often below 5.0 mg/l. The river recovers rapidly as shown in Figure VI-5. Near the confluence with the Potomac River, the monthly average was 6.0 mg/l and higher, and the average monthly BOD was about 2.0 mg/l (Figure VI-6).

BOD - DO CONCENTRATIONS*
MAIN STEM SHENANDOAH RIVER at BERRYVILLE, W. Va.
1961 - 1964

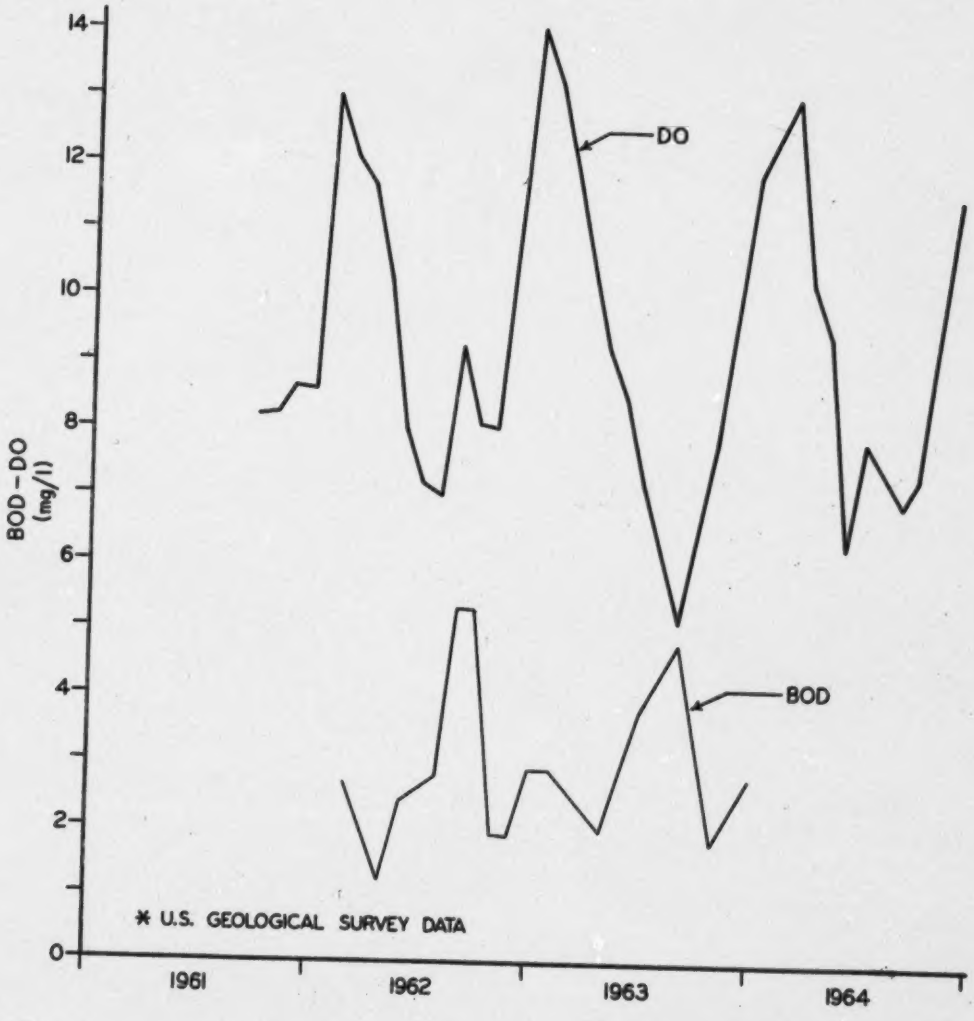


FIGURE VI-4

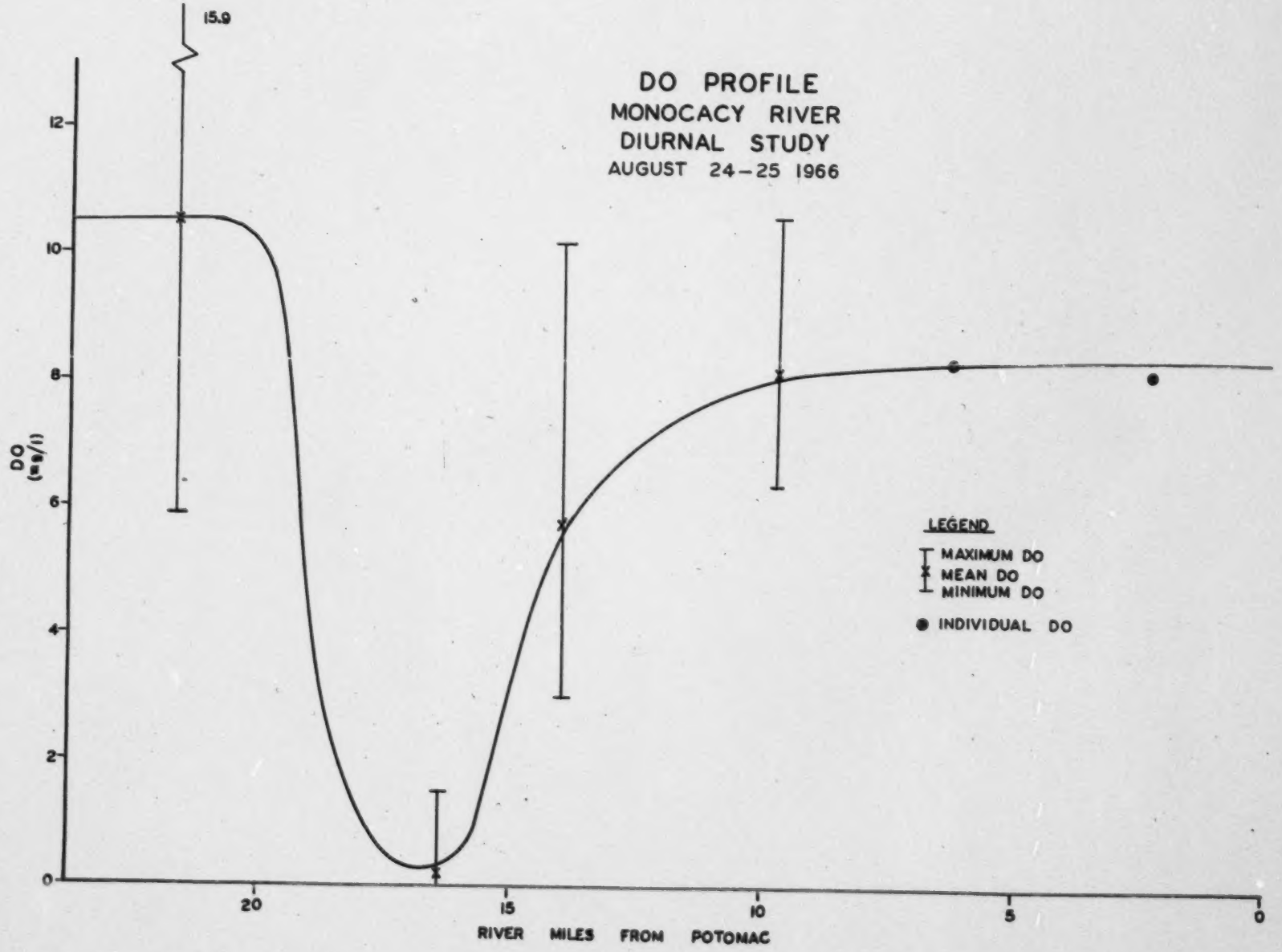
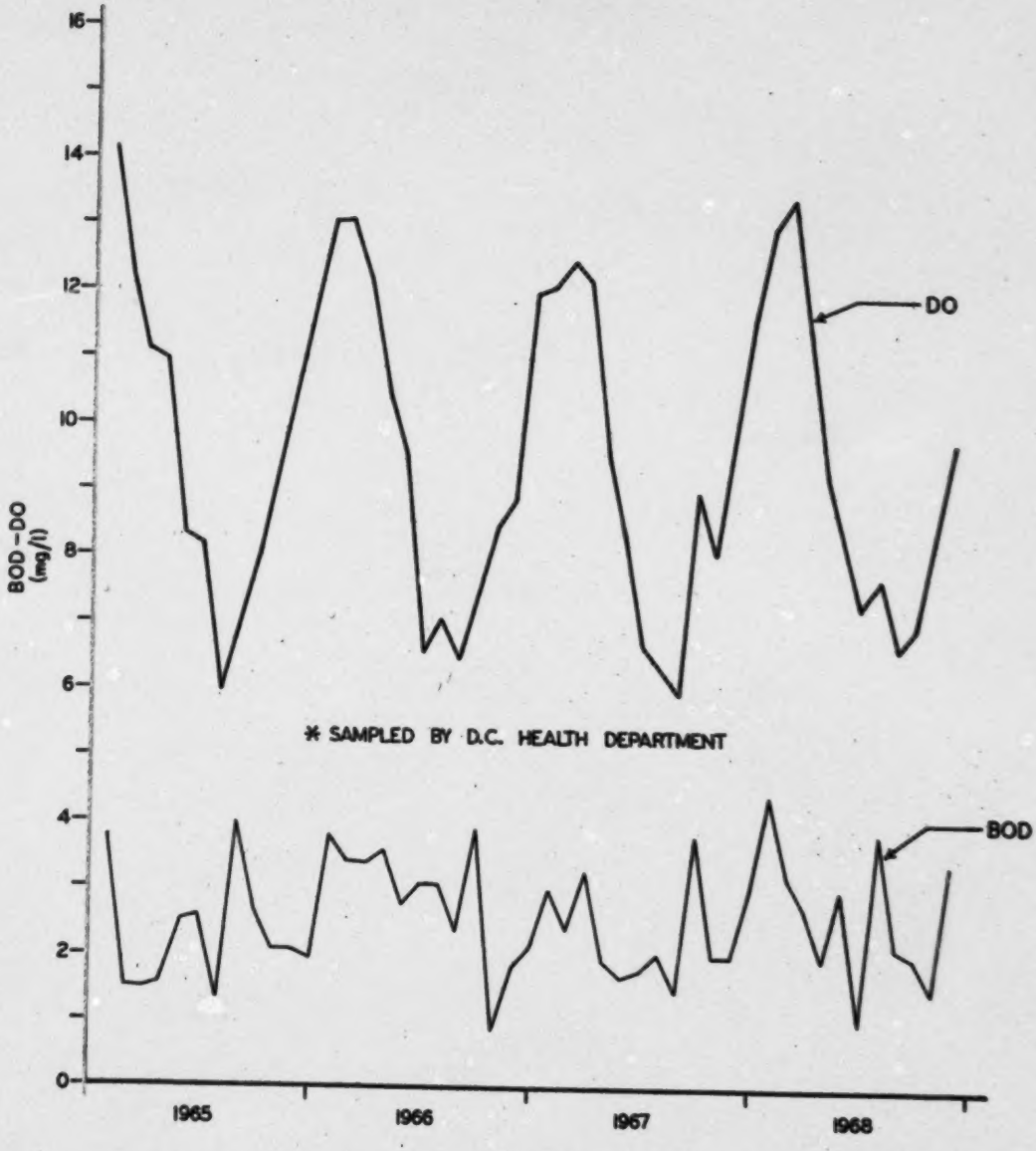

15.9
DO PROFILE
MONOCACY RIVER
DIURNAL STUDY
AUGUST 24-25 1966
DO (mg/l)
12
10
8
6
4
2
0
LEGEND
MAXIMUM DO
MEAN DO
MINIMUM DO
INDIVIDUAL DO
20
15
10
5
0
RIVER MILES FROM POTOMAC

FIGURE VI-5

MEAN MONTHLY BOD and DO *

MONOCACY RIVER near CONFLUENCE with POTOMAC RIVER

1965 – 1968



* SAMPLED BY D.C. HEALTH DEPARTMENT

FIGURE VI-6

H. MAIN STEM POTOMAC RIVER

From the confluence with the North and South branches to the Potomac Estuary the major wastewater discharges to the main stem are:

Facility	Wastewater Flow (mgd)	Discharge BOD (lbs/day)
Paw Paw, W. Va.	0.10	50
Hancock, Md.	0.38	45
Williamsport, Md.	0.23	430
Shepherdstown, W. Va.	0.14	235
Halfway, Md.	0.25	260
Sharpsburg, Md.	0.10	109
Brunswick, Md.	0.40	435

Figures VI-7, VI-8, and VI-9 for the Potomac River at Williamsport, Point of Rocks, and Great Falls, respectively, show that the mean monthly DO at these stations was usually greater than 6.0 mg/l except for the months of July and August 1963 at Great Falls. DO concentrations greater than 6.0 mg/l were also recorded during the July and August 1969 surveys.

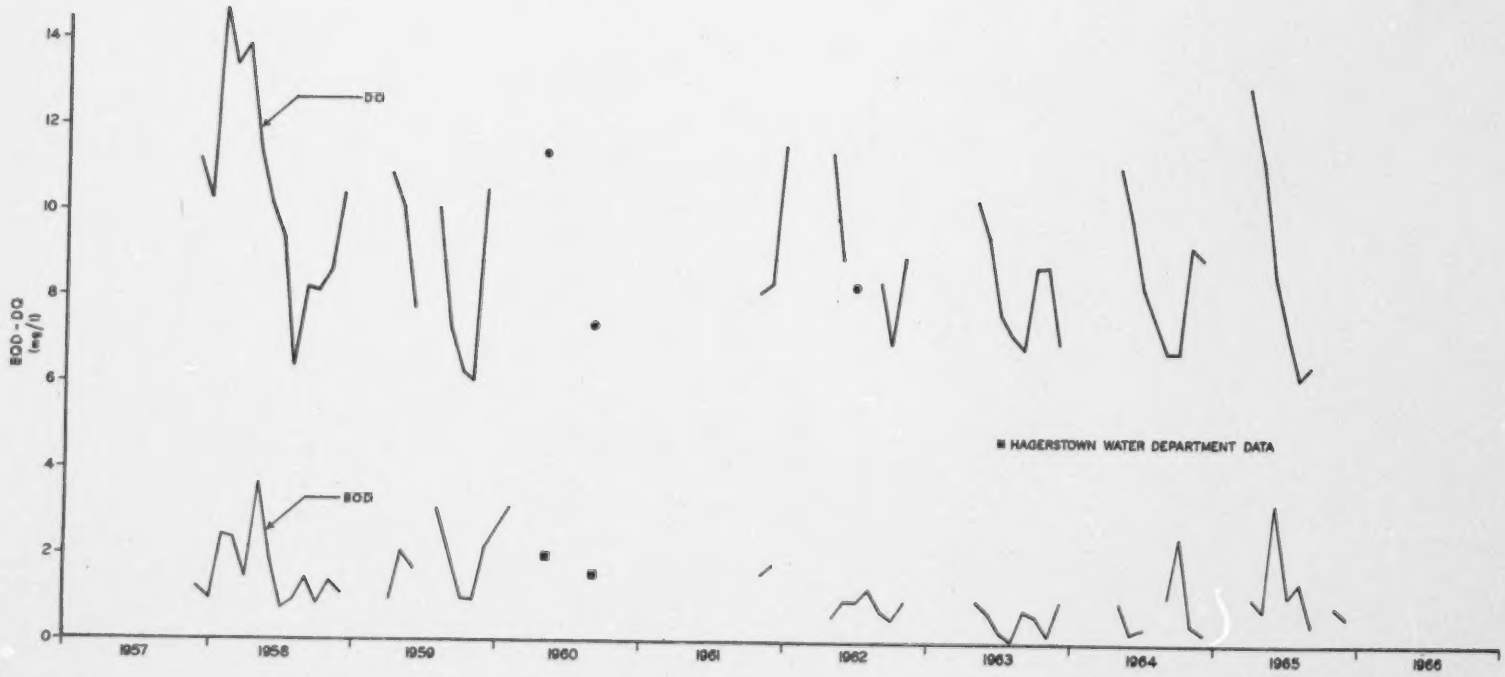
The BOD levels at all three stations, also shown in Figures VI-7, VI-8, and VI-9, indicate low levels of oxidizable organic matter. At Great Falls, the concentration of BOD ranged from about 1.0 to 4.0 mg/l while at Williamsport the levels were lower, ranging from about 0.5 to 3.0 mg/l.

MEAN MONTHLY BOD and DO*

POTOMAC RIVER at WILLIAMSPORT, Md.

RIVER MILES = 210.0

1957 – 1966



* HAGERSTOWN WATER DEPARTMENT DATA

FIGURE VI-7

VI-16

MEAN MONTHLY BOD and DO *

POTOMAC RIVER at POINT of ROCKS

RIVER MILES = 163.0

1965 – 1968

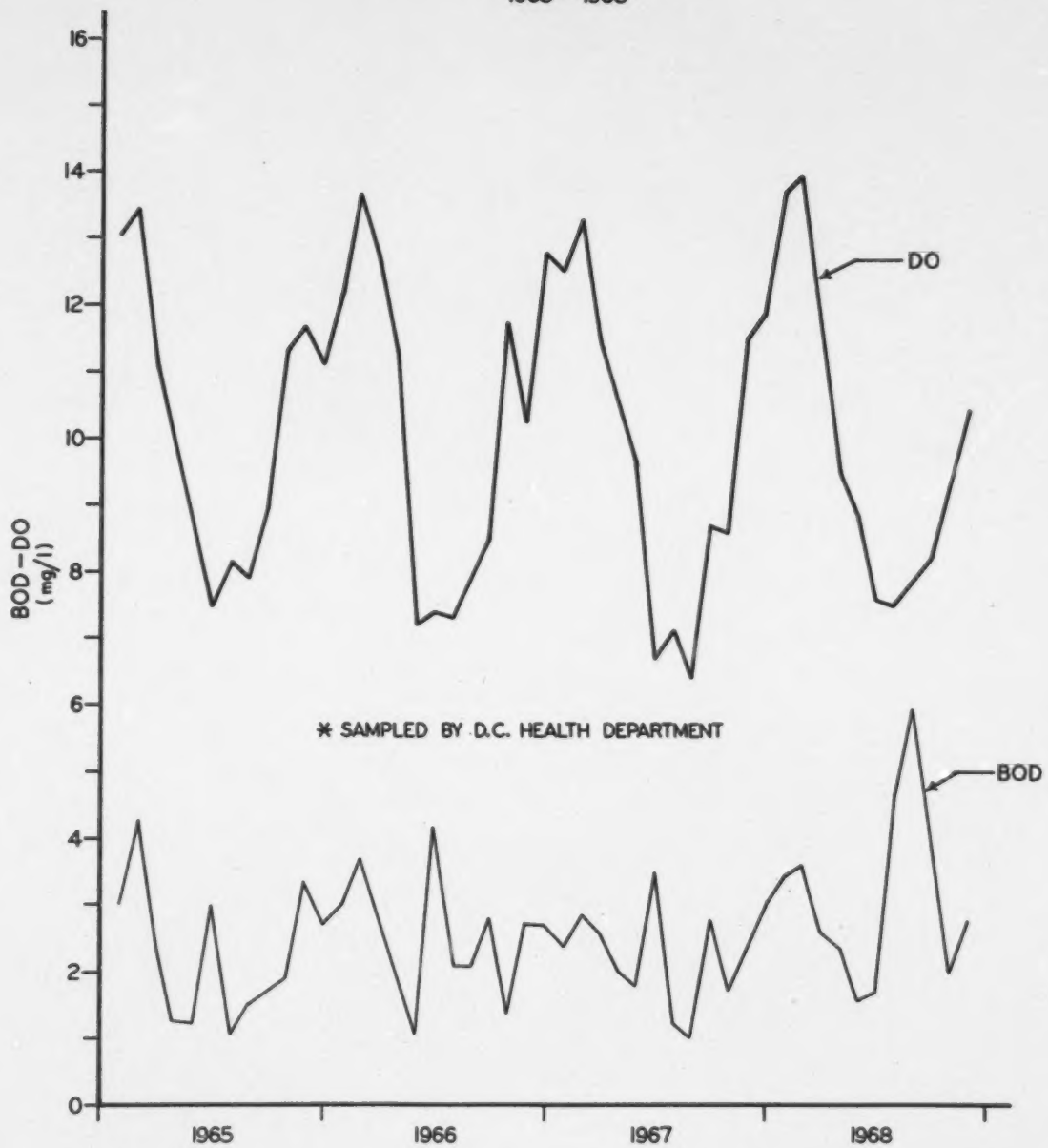


FIGURE VI-8

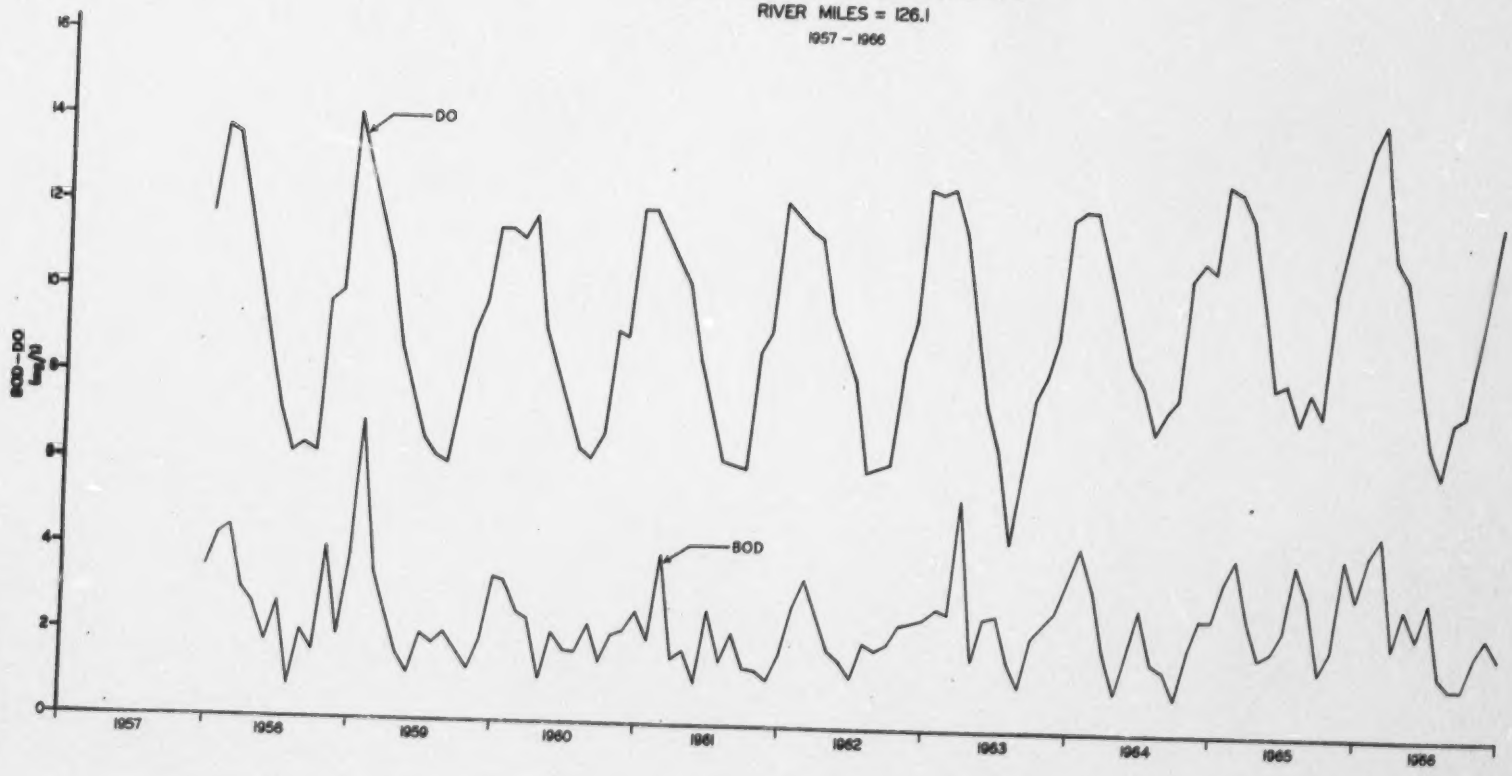

MEAN MONTHLY BOD and DO
POTOMAC RIVER at GREAT FALLS, Md.
RIVER MILES = 126.1
1957 – 1966
BOD-DO mg/l
DO
BOD
0
2
4
6
8
10
12
14
16
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966

FIGURE VI-5

The monthly BOD loadings in the Potomac River at Great Falls from January to August 1969 are shown in Table VI-1. The average BOD load (107,800 lbs/day) during this period represents 45 percent of the total BOD discharged into the upper Potomac Estuary from all sources.

TABLE VI-1

FRESH WATER INFLOW BOD CONTRIBUTION

Potomac River near Washington, D. C.

Month	Average Monthly Flow (cfs)	BOD (lbs/day)
January	4,000	80,000
Febuary	6,700	112,000
March	8,400	127,000
April	7,100	138,000
May	3,900	100,000
June	2,300	67,000
July	2,800	81,000
August	8,100	157,000
Average	5,400	107,800

CHAPTER VII

PESTICIDES

A. GENERAL

Pesticides are chemical compounds, either natural or synthetic, used to control unwanted or noxious animals and plants. They fall into four general classifications depending upon their chemical composition:

(1) Chlorinated hydrocarbons (DDT - dieldrin, heptachlor, endrin, aldrin, etc.)

(2) Organic phosphorus compounds (parathion, malathion, phosdrin, etc.)

(3) Other organic compounds (denithophenols, carbonates, etc.)

(4) Inorganic compounds (copper sulfate, lead arsenate, zinc phosphide, etc.)

The chlorinated hydrocarbons constitute the most common type of insecticide currently used.

B. WATER QUALITY CRITERIA

The Committee on Water Quality Criteria, Federal Water Pollution Control Administration, has published recommended pesticides concentrations for various water uses [3]. Criteria pertaining to the common chlorinated hydrocarbons are as follows:

1. Public Water Supplies

Constituent	Permissible* Criteria (ug/l)
Aldrin	17.0
DDT	42.0
Dieldrin	17.0
Endrin	1.0
Heptachlor	18.0
Heptachlor epoxide	18.0

2. Fish and Aquatic Life

Aldrin, BHC, endrin, heptachlor, DDT, and dieldrin are all acutely toxic to aquatic populations at concentrations of 5 ug/l and less. Based on the assumption that 1/100 of this concentration represents a reasonable application factor, the levels of these substances in the marine or freshwater environment should not exceed 50 nanograms/liter (0.05 ug/l).

3. Wildlife

A limited knowledge of the dynamics of biological magnification in wildlife habitats does not permit the realistic establishment of tolerable pesticide criteria.

* The permissible levels are based upon recommendations of the Public Health Service Advisory Committee on use of the PHS Drinking Water Standards.

4. Agricultural (Irrigation, farmstead, and livestock water supply)

Constituent	Recommended* Criteria (ug/l)
Aldrin	17.0
DDT	42.0
Dieldrin	17.0
Endrin	1.0
Heptachlor	18.0
Heptachlor epoxide	18.0

C. ANALYSIS AND DISCUSSION

Analytical pesticide data for the upper Potomac River basin, are presented in Tables VII-1 through VII-5. The long-term data (Tables VII-1 and VII-3) were collected at three water quality network stations (FWPCA) and the remaining data were collected at CTSL stations during September 1968 (Table VII-4) and August 1969 (Tables VII-5). All samples were analyzed at the FWPCA laboratory in Cincinnati, Ohio within certain detectable limits (Table VII-6).

An examination of the results indicates that most pesticide determinations were negative; however, many samples showed trace quantities of certain chlorinated hydrocarbon pesticides and samples collected in the Potomac River at Great Falls and in Antietam Creek showed significant quantities of DDT, dieldrin, and endrin. The 0.666 ug/l of dieldrin and the 0.17 ug/l of DDT measured in Antietam Creek and the maximum endrin concentration (0.094 ug/l) measured at Great Falls exceeded the recommended criteria of these constuents for fish and aquatic life (0.05 ug/l).

* Same as criteria prescribed by PHS Drinking Water Standards

In view of the limited number of pesticide analyses currently available, it is essential that a more representative water quality sampling program having a minimum duration of one year be initiated to obtain the necessary data for assessing potential pesticide pollution problems in the upper Potomac basin.

TABLE VII-1

PESTICIDE DATA

POTOMAC RIVER AT MEMORIAL BRIDGE

DATE SAMPLED	ALDRIN WHL SMPL UG/L	BHC WHL SMPL UG/L	DDD WHL SMPL UG/L	DDE WHL SMPL UG/L	DDT WHL SMPL UG/L	DIELDRIN WHL SMPL UG/L	ENDRIN WHL SMPL UG/L	HCHLR WHL SMPL UG/L	HCHLR-EP WHL SMPL UG/L
09/23/64	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000N*	0.000
09/22/65	0.000	0.000	0.007	0.000	0.000	0.003	0.000	0.000	0.003
09/29/67	0.000	0.000	0.000	0.000	0.000	0.025	0.000	0.000	0.000

* Legend:

N - Constituent was present, but at a barely detectable level.

K - Constituent was present at a level less than the value given.

L - Constituent was present at a level greater than the value given.

TABLE VII-2

PESTICIDE DATA

POTOMAC RIVER AT GREAT FALLS

DATE SAMPLED	ALDRIN SAMPLE UG/L	BHC SAMPLE UG/L	DDD SAMPLE UG/L	DDE SAMPLE UG/L	DDT SAMPLE UG/L	DIELDRIN SAMPLE UG/L	ENDRIN SAMPLE UG/L	HCHLR SAMPLE UG/L	HCHLR-EP SAMPLE UG/L
07/07/58	0.000	0.000N	0.001	0.000N	0.000N	0.001K	0.000N	0.000N	0.007
09/04/58	0.000	0.000	0.000	0.001K	0.000	0.001K	0.000	0.000	0.000N
07/06/59	0.000	0.000	0.002	0.000	0.000	0.000N	0.000	0.000	0.000
10/05/59	0.000	0.000N	0.000	0.002	0.000	0.001K	0.000	0.000	0.000
07/18/60	0.000	0.000	0.002	0.001K	0.001K	0.002	0.000	0.000	0.000
10/10/60	0.000	0.000	0.000	0.001	0.000	0.002	0.000	0.000	0.001K
09/05/61	0.000	0.000	0.003	0.001K	0.000	0.002	0.000	0.000	0.001K
07/16/62	0.000	0.000	0.000N	0.000	0.000	0.003	0.000	0.000	0.000
09/17/62	0.000N	0.000	0.001	0.001K	0.000	0.002	0.000	0.000	0.000
07/09/63	0.009N	0.000	0.000N	0.000	0.000	0.005	0.000	0.000	0.000
09/23/63	0.000	0.000	0.001	0.001K	0.000	0.001	0.000N	0.000	0.000N
06/25/64	0.000	0.000	0.004	0.002	0.002	0.001	0.000	0.000	0.000
09/10/64	0.000	0.000N	0.001K	0.001K	0.001K	0.001K	0.000	0.000	0.001K
09/23/64	0.000	0.000	0.000	0.000N	0.000N	0.040L	0.094L	0.000	0.000
09/22/65	0.000	0.000	0.000	0.000	0.000	0.016	0.000	0.000N	0.000N
09/18/66	0.000	0.000	0.012	0.000	0.038	0.000	0.000	0.000	0.000
09/29/67	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE VII-3

PESTICIDE DATA

SHENANDOAH RIVER AT BERRYVILLE, VIRGINIA

DATE SAMPLED	ALDRIN SAMPLE UG/L	BHC SAMPLE UG/L	DDD SAMPLE UG/L	DDE SAMPLE UG/L	DDT SAMPLE UG/L	DIELDRIN SAMPLE UG/L	ENDRIN SAMPLE UG/L	HCHLR SAMPLE UG/L	HCHLR-EP SAMPLE UG/L
01/29/64	0.000	0.000	0.000	0.000N	0.000N	0.001	0.000N	0.000	0.000
02/26/64	0.000	0.000	0.001K	0.000N	0.000N	0.001	0.000N	0.000	0.000
09/23/64	0.000	0.000	0.083	0.002	0.026	0.005	0.009	0.000	0.000
09/22/65	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
09/13/66	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000N
09/29/67	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000

TABLE VII-4

PESTICIDE DATA -1968

STREAM	LOCATION	DATE	ALDRIN* (ug/l)	BHC* (ug/l)	DDD* (ug/l)	DDE* (ug/l)	DDT* (ug/l)	DIELDRIN* (ug/l)	ENDRIN* (ug/l)	HCHLR* (ug/l)	HCHLR-EP* (ug/l)
Large Stream	Berkeley Co. Public Service District, Bunker Hill, W. Va.	9/10/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Lake Spring	Martinsburg, W. Va.	9/10/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Back Creek	Rt. 9 Bridge west of Hodgesville, W. Va.	9/9/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Back Creek	Rt. 45 Bridge Millgap, W. Va.	9/10/68	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Opequon River	Rt. 51 Bridge near Middleway, W. Va.	9/10/68	0.000	0.000	0.000	0.000	0.000	0.014	0.000	0.000	0.000
Opequon River	Concrete Bridge near Bedington, W. Va.	9/10/68	0.000	0.000	0.000	0.000	0.000	0.008	0.000	0.000	0.000

* Limit of Sensitivity - < 0.002 ug/l

TABLE VII-5

PESTICIDE DATA - AUGUST 1969

Sampling Location	Collection Date	Results
Potomac River at Chain Bridge	8/11/69 1130	no compounds detected
Monocacy River at Reich's Bridge	8/12/69 1645	12 ng/l lindane
Antietam Creek at Sharpsburg	8/14/69 1315	66 ng/l dieldrin 170 ng/l DDT
Potomac River at Cumberland	8/13/69 1430	no compounds detected

TABLE VII-6

PESTICIDES ANALYZED AND
MINIMUM DETECTABLE LIMITS

Compound	Minimum Detectable Concentration ng/l
Dieldrin	5
Endrin	5
DDT	10
DDE	5
Heptachlor	5
Heptachlor Epoxide	5
Aldrin	5
BHC	5
Endosulphan	5
Chlordane (Tech.)	25
Toxaphene	1,000
Methoxychlor	25

* ng/l = nannograms/liter

CHAPTER VIII

THERMAL DISCHARGES

A. GENERAL

Thermal discharges may be defined as any discharge which has been artificially heated above the natural temperature of the receiving water. Tremendous amounts of water are used by the power generating industries for condenser cooling and subsequently discharged as thermal wastes. While power generation represents the principal source of thermal wastes in the upper Potomac River basin, other industries involved with manufacturing processes requiring cooling water also contribute a significant amount of thermal discharge.

The emission of heated water, especially in large quantities, exerts an adverse effect on the aquatic environment because of changes in the physical, chemical, and biological properties of water. Foremost among these effects are (1) a reduction in the solubility of oxygen and other gases, (2) an increase in metabolic activity with abnormal growth and reproduction patterns in all freshwater and marine organisms, and (3) a greater sensitivity of these organisms to toxic substances due to synergistic action.

An acute awareness and concern over large thermal waste discharges has recently occurred. This concern is manifested by the establishment of temperature criteria in all Federal-State water quality standards. The temperature criteria applied to Maryland streams which receive significant quantities of thermal wastes are presented in Table VIII-1.

TABLE VIII-1

WATER QUALITY STANDARDS (TEMPERATURE) FOR

SELECTED STREAM REACHES IN THE UPPER POTOMAC RIVER BASIN

State	Stream	Zone	Temperature Criteria
Maryland	North Branch Potomac River (interstate)	West Virginia-Maryland State Line to Dam at Luke, Maryland	72° F. (22.2° C.)
Maryland	North Branch Potomac River (interstate)	Dam at Luke, Maryland to Dam at Cumberland, Maryland	100° F. (37.8° C.)
Maryland	North Branch Potomac River (interstate)	Dam at Cumberland to confluence with South Branch Potomac River	93° F. (33.9° C.)
Maryland	Antietam Creek (interstate)	Pennsylvania-Maryland State Line to mouth	93° F. (33.9° C.)
Maryland	Potomac River (interstate)	Allegany-Washington County Line to Washington, D.C.	93° F. (33.9° C.)
Virginia	South River (intrastate)	Headwaters to mouth	95° F. (35° C.)
Virginia	Middle River (intrastate)	Headwaters to mouth	95° F. (35° C.)
Virginia	South Fork Shenandoah River (intrastate)	Headwaters to mouth	95° F. (35° C.)
Virginia	Shenandoah River (intrastate)	Headwaters to mouth	95° F. (35° C.)
West Virginia	Stony River (intrastate)	Headwaters to mouth	87° F. (30.6° C.)

B. SOURCES AND THERMAL CONDITIONS

Major sources of thermal wastes in the upper Potomac basin are presented in Table VIII-2. Also given are the receiving waters and waste flow for each source.

Average monthly temperatures for the past five years of record at representative stations throughout the upper Potomac River basin are presented in Table VIII-3. These temperatures were extracted from the compilation of data published annually by the Interstate Commission on the Potomac River Basin (INCOPOT). The temperature values shown in the table indicate that water quality standards were being met in the four sub-basins investigated despite the fact that these streams receive large quantities of heated wastes!

The most critical sub-basin was the North Branch Potomac where temperatures exceeding 30°C. (86°F.) were quite common. Heated discharges from the West Virginia Pulp and Paper Company (between Stations 338.2 and 337.5) generally raised stream temperatures more than 5°C. Moreover, the Celanese Fibers Company in Amcelle, Maryland (Station 314) created an additional rise in temperature averaging 3°C. Water temperatures in the North Branch Potomac at Cumberland, Maryland (Station 308) remained relatively high due to the heated discharge from Potomac Edison Company's steam electric plant immediately upstream. If future expansion of these industries result in greater usage of cooling water, a thermal pollution problem in the North Branch Potomac River will occur unless corrective measures are undertaken.

TABLE VIII-2

MAJOR THERMAL DISCHARGES

Upper Potomac River Basin

	Facility	Sub-Basin	Receiving Stream	Waste Flow (MGD)
1.	Virginia Elec. & Power (Mt. Storm, W. Va.)	North Branch Potomac	Mt. Storm Lake & Stony River	720*
2.	W. Va. Pulp & Paper Company (Luke, Maryland)	North Branch Potomac	North Branch Potomac River	45
3.	Celanese Fibers Company (Amcelle, Maryland)	North Branch Potomac	North Branch Potomac River	60
4.	Kelley Springfield Company (Cumberland, Maryland)	North Branch Potomac	North Branch Potomac River	4.8
5.	Potomac Edison Company (Cumberland, Maryland)	North Branch Potomac	North Branch Potomac River	45
6.	Potomac Edison Company (Williamsport, Maryland)	Middle Potomac	Potomac River	234
7.	Marquette Cement Mfg. Co. (Hagerstown, Maryland)	Antietam	Antietam Creek	8.1
8.	Hagerstown Mun. Elec. Co. (Hagerstown, Maryland)	Antietam	Antietam Creek	33.4
9.	E. I. Dupont DeNemours & Co, Inc. (Waynesboro, Virginia)	South Fork Shenandoah	South River	15.9
10.	Reynolds Metals Company (Grottoes, Virginia)	South Fork Shenandoah	South River	2.2
11.	Westinghouse Electric (Verona, Virginia)	South Fork Shenandoah	Storm sewers -- Middle River	0.60
12.	American Safety Razor Company (Verona, Virginia)	South Fork Shenandoah	Middle River	0.35
13.	American Viscose Corporation (Front Royal, Virginia)	South Fork Shenandoah	South Fork Shenandoah River	0.72
14.	Northern Virginia Power Company (Cedarville, Virginia)	Main Stem Shenandoah	Shenandoah River	10.6
15.	Pepco Dickerson General Station	Lower Potomac	Potomac River	355

*Includes condenser water only

TABLE VIII-3

TEMPERATURE DATA*

UPPER POTOMAC RIVER BASIN
(INCOPOT)

Year	Month	North Branch				Shenandoah				Antietam	Potomac	
		338.2 °C	337.5 °C	414.5 °C	408.0 °C	171-176 °C	171-160 °C	171-54 °C	171-44 °C	180-17 °C	210 °C	125.6 °C
1964	June	15	19	22	25	23	23	23	25	19	20	24
	July	20	26	30	31	24	25	24	26	-	-	25
	Aug.	19	25	25	29	22	22	23	25	24	22	24
	Sept.	15	19	25	28	18	19	25	25	20	19	19
1965	June	21	26	27	31	18	20	17	18	21	21	25
	July	21	27	30	31	24	25	26	27	25	24	26
	Aug.	17	25	30	31	22	23	23	26	25	22	26
	Sept.	15	22	23	29	21	23	28	28	-	-	24.6
1966	June	17	19	27	24	21	22	26	26	-	21	25
	July	22	26	29	33	25	24	27	29	-	17	27
	Aug.	16	26	-	31	23	24	24	26	25	25	-
	Sept.	15	20	35	20	17	17	17	17	-	22	-
1967	June	17	20	28	28	24	24	15	16	22	22	23
	July	19	21	27	27	22	24	25	25	22	23	24
	Aug.	19	22	28	30	22	22	26	26	22	25	24
	Sept.	10	13	23	23	19	20	24	25	23	22	21
1968	June	22	23	-	27	19	20	25	23	18	19	22
	July	22	29	-	34	22	24	29	28	26	27	26
	Aug.	22	35	32	29	24	25	24	26	-	-	26
	Sept.	18	28	27	30	18	19	22	20	-	-	22

* Mean Monthly

In addition to INCOPOT data, other temperature data collected by CTSL and the U. S. Geological Survey were also analyzed. A water quality survey in the North Branch Potomac River was conducted by CTSL during August 1967. Temperatures ranging from 28°C. to 36°C. were observed at the Luke-Piedmont Bridge, downstream from the West Virginia Pulp and Paper Company. Although water quality standards assigned to this stream reach by the State of Maryland were not being contravened based upon CTSL data, a potential problem nevertheless exists.

The U. S. Geological Survey maintains gaging stations on the North Branch Potomac River at Luke and Cumberland, Maryland, and routinely records water temperature data at these gages. USGS data yielded results comparable to those already presented.

Extensive temperature and corresponding biological data have not been collected in the immediate vicinity of the two largest thermal waste discharges in the upper Potomac basin; namely, Virginia Electric and Power Company at Mount Storm, West Virginia and Potomac Edison Power Company at Dickerson, Maryland. It is necessary to collect such data before the effects of these facilities on the thermal regime of the receiving streams can be evaluated.

CHAPTER IX
MINE DRAINAGE - GENERAL SUMMARY

A cooperative Federal-State comprehensive water quality study of the North Branch Potomac River basin was conducted from March 1968 to May 1969 to identify the principal sources of mine drainage and to ascertain the effects of acid tributary flows on the North Branch Potomac River [4]. Eighteen stations were sampled bi-weekly for pertinent water quality indicators. The data obtained during this survey indicated that mine drainage has created extremely low pH levels which are destroying all forms of aquatic life in more than 40 miles of the North Branch Potomac and more than 100 miles of tributary streams. Moreover, the excessive acid, solids, and metals such as iron and manganese in mine drainage are having a deleterious effect on the North Branch as a source of municipal and industrial water supply.

The tributary streams in the Potomac basin producing most of the acid are outlined below:

Watershed	Average Acid Load (lbs/day)	State
Elk Run	35,000	West Virginia
Laurel Run	13,000	Maryland
Buffalo Creek	15,000	West Virginia
Abram Creek	8,000	West Virginia
Stony River	4,500	West Virginia
Three Forks Run	3,300	Maryland
Piney Swamp Run	3,200	West Virginia
Unnamed Tributary	1,500	West Virginia
Lostland Run	1,000	Maryland

Approximately 79,000 lbs/day of acid is presently being contributed by streams within the State of West Virginia and approximately 39,000 lbs/day by streams within the State of Maryland. These estimates represent 67 percent and 33 percent, respectively, of the total acid load in the North Branch Potomac River at Beryl, West Virginia. Although the Beryl station drains 287 square miles, approximately 54 percent of its acid originates from only 20.6 square miles comprising the watersheds of Elk Run, Laurel Run, and Buffalo Creek.

A summary of the 1968-69 water quality data for the North Branch Potomac River is presented in Figure IX-1. An examination of these data indicates that the North Branch Potomac was continuously acid from Steyer, Maryland to Beryl, West Virginia, a reach representing approximately 30 miles. This stream reach is also characterized by pH levels generally less than 4.0, whereas the Maryland water quality standards prescribe a minimum pH of 6.0. In the past, large alkaline loads in the Luke-Westernport, Maryland area (West Virginia Pulp and Paper Company and Upper Potomac Commission's sewage treatment plant) have normally prevented acidic conditions in the North Branch Potomac from extending further downstream.

Recently, however, a reduction in the alkalinity from the West Virginia Pulp and Paper Company, combined with a "slug" of mine drainage flushed out of the critical acid-producing watersheds by excessive rainfall, resulted in exceptionally low pH values in the North Branch Potomac River beyond Cumberland, Maryland. The data collected in the vicinity of Cumberland during a special CTSL survey

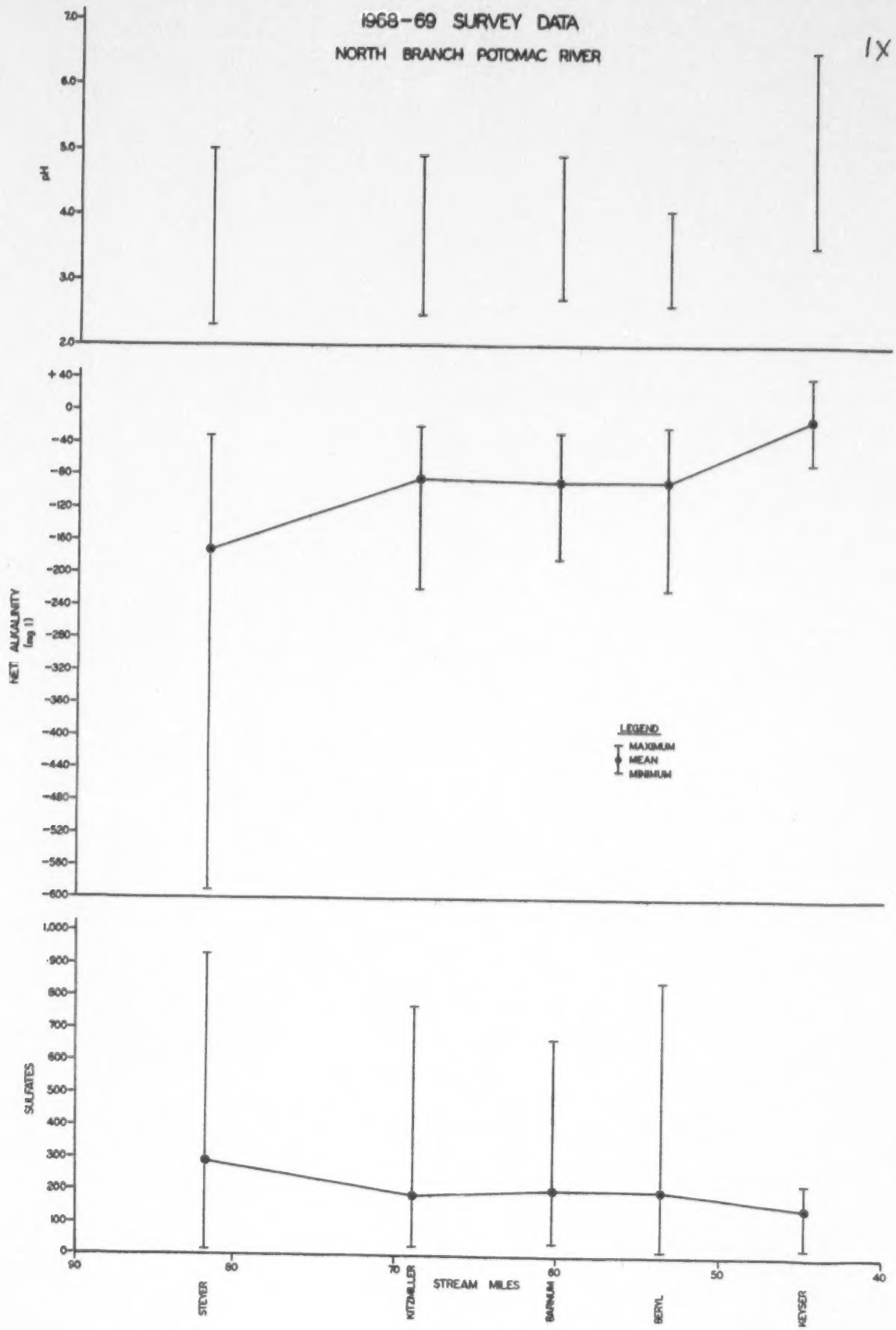

1968-69 SURVEY DATA
NORTH BRANCH POTOMAC RIVER
pH
7.0
6.0
5.0
4.0
3.0
2.0
NET ALKALINITY (mg/l)
+40
0
-40
-80
-120
-160
-200
-240
-280
-320
-360
-400
-440
-480
-520
-560
-600
LEGEND
MAXIMUM
MEAN
MINIMUM
SULFATES
1,000
900
800
700
600
500
400
300
200
100
0
90
80
70
60
50
40
STREAM MILES
STEYER
KITZMILLER
BARNUM
BERYL
KEYSER

FIGURE IX-1

on August 18, 1969, exhibited a pH range of 3.3 to 3.6. These low pH levels appear to be the cause of a fish kill which occurred the preceding week near Oldtown, Maryland approximately ten miles downstream from Cumberland.

Since there are no large natural alkalinity sources in the North Branch Potomac River upstream from Beryl, an extensive mine drainage control program to eliminate practically all acid discharges is necessary to attain a water quality commensurate with approved water quality standards. Based upon a preliminary appraisal, an annual expenditure of $5,000,000 is required to provide necessary preventive, collection, and treatment measures in the seven most critical watersheds of the Potomac basin. The first cost figure was estimated to be about $32,500,000.

CHAPTER X

NUTRIENTS

For the 1966 calendar year, a 40-station stream sampling network was maintained by CTSL in the Potomac River basin. Based upon three water quality network stations and data from the CTSL wastewater loading surveys of 1966 and 1968, a detailed report on nutrient sources and distribution has been prepared [5]. To further define the nutrient forms entering the estuary from the upper basin, weekly monitoring of nutrients at Great Falls is currently being conducted as a component of a nutrient transport study in the Potomac Estuary.

A. SOURCES

1. Wastewater Loadings

As of December 1968, there were 256 wastewater discharges in the upper Potomac River basin [6]. In the upper basin about 18,430 lbs/day of total PO_4 and 10,680 lbs/day of TKN were discharged to the surface waters (Table X-1). For a sewered population of 403,500 this reduces to 0.045 and 0.026 lbs/capita/day of phosphorus and nitrogen, respectively.

Nutrient loadings from industrial wastewater discharges are about 7,700 lbs/day of total PO_4 and 4,600 lbs/day of TKN. The industrial contribution to wastewater nutrient loadings in the upper basin is about 42 percent of the total PO_4 (TPO_4) and about 43 percent of the total nitrogen. The amount of NO_2 + NO_3 nitrogen in both the industrial and municipal wastewater discharges is insignificant.

TABLE X-1

NUTRIENT LOADINGS FROM WASTEWATER DISCHARGES
BY SUB-REGIONS*

Sub-Region	Population Served	LOADING AFTER TREATMENT BOD lbs/day	TKN lbs/day	TPO_4 lbs/day
North Branch	79,200	55,300	1,750	4,850
South Branch and Upper Region	17,300	2,720	370	460
Opequon	34,800	3,470	480	1,100
Conococheague and Upper Middle Region	26,900	4,250	710	1,050
Antietam and Middle Region	61,500	7,980	890	2,380
Shenandoah	108,500	31,800	4,890	6,360
Catoctin Creeks Md. and Va.	5,400	740	110	220
Monocacy	62,500	4,220	1,380	1,830
Lower Region	7,400	200	100	180
TOTAL	403,500	110,680	10,680	18,430

* A Sub-Region may include discharges to the small tributaries and to the main stem of the Potomac.

2. Land Runoff and Other Sources

To determine the amount of nutrients coming from land runoff, analyses of loadings from areas with three distinct land uses (forest, agricultural, and urban) were made. Using the Catoctin Creek (Maryland) watershed basin as primarily agricultural, the Patterson Creek watershed as forested, and Rock Creek watershed as urban, the effect of land uses on the contribution of nutrients to the surface waters is illustrated in Table X-2. These three areas receive a relatively small wastewater volume.

Table X-2

NUTRIENT LOADINGS FROM WATERSHEDS WITH VARYING LAND USE

Watershed and Land Use	Drainage Area (sq mi)	T PO_4 as PO_4 (lbs/day/sq mi)	NO_2 + NO_3 as N (lbs/day/sq mi)	TKN as N (lbs/day/sq mi)
Patterson Creek (Forest)	279	0.50	2.02	0.41
Catoctin Creek (Agric.)	109	1.25	5.30	0.65
Rock Creek (Urban)	77	1.10	2.70	0.67

Using the same land use designations that the U. S. Corps of Engineers used in their 1958 study [7], the nutrient loading from land runoff was determined (Table X-3). It should be noted that the largest contribution of nutrients is from agricultural runoff even though over 62 percent of the basin is covered by forest.

B. SPATIAL DISTRIBUTION 1966

1. Phosphorus

As can be seen in the summary of the nutrient data for the major sub-basins in Table X-4, the phosphorus concentrations were at least three times greater in the Monocacy River, Opequon Creek, and Antietam Creek sub-basins than in the remaining five sub-basins. These three sub-basins are primarily agricultural but receive considerable quantities of municipal wastewater. These higher concentrations are also reflected in large PO_4 yields of from 3.6 to 4.8 lbs/day sq. mi. as shown in Table X-4.

2. Nitrite + Nitrate and Total Kjeldahl Nitrogen (TKN)*

The Conocheague, Antietam, Opequon, and Monocacy sub-basins had an average NO_2 + NO_3 nitrogen of 1.4 mg/l and greater. The Conococheague and Monocacy sub-basins had nitrite and nitrate yields of over 10 lbs/day/sq. mi., almost twofold larger than that of the remaining four sub-basins.

* TKN in this report is defined as organic plus ammonia nitrogen.

TABLE X-3

ESTIMATED NUTRIENT LOADINGS FROM LAND RUNOFF

UPPER POTOMAC RIVER BASIN

Land Use	Area	T. PO_4 as PO_4		$NO_2 - NO_3$ as N		TKN as N	
	(sq. mi.)	(lbs/day/sq.mi.)	(lbs/day)	(lbs/day/sq.mi.)	(lbs/day)	(lbs/day/sq.mi.)	(lbs/day)
Agriculture*	4,100	1.25	5,100	6.0	24,500	0.65	2,660
Forest	6,800	0.50	3,400	2.0	13,600	0.40	2,720
Urban	100	1.10	110	3.0	300	0.65	65
Total Upper Basin	11,000	0.78	8,610	3.2	38,400	0.50	5,445

* Agricultural use includes both crop land and pastures

TABLE X-4

COMPARISON OF ANNUAL AVERAGE NUTRIENT CONCENTRATIONS
AND LOADINGS
1966

Major Sub-basins of Upper Potomac River Basin

Sub-basin (Station)	Drainage Area (sq.mi.)	T. PO_4 as PO_4			NO_2 - NO_3 as N			TKN as N*
		(mg/l)	(lbs/day)	(lbs/day/sq.mi.)	(mg/l)	(lbs/day)	(lbs/day/sq.mi.)	(mg/l)
North Branch (Oldtown, Md.)	1328	.532	2,551	1.92	.378	3,267	2.46	.784
South Branch (Romney, W. Va.)	1450	.092	1,535	1.06	.296	3,655	2.52	-
Conococheague Cr. (Williamsport, Md.)	469	.327	1,226	2.61	1.593	5,317	11.34	.019
Antietam Creek (Antietam, Md.)	283	1.996	1,353	4.78	1.429	1,321	4.67	.536
Opeqon Creek (Martinsburg, W. Va.)	309	1.511	1,109	3.59	2.149	1,817	5.88	.264
Shenandoah River (Bloomery, W. Va.)	3012	.356	5,105	1.69	.654	6,714	2.23	.580
Monocacy River (Frederick, Md.)	813	1.176	3,385	4.16	1.744	8,661	10.65	.693
Potomac River (Great Falls, Md.)	11460	.379	17,013	1.48	.903	49,009	4.28	.270

* Based on 6 months of sampling.

X-9

Since the TKN determination was initiated in the midsummer of 1966, annual loadings were not calculated for this parameter. The average TKN concentration ranged from 0.017 to 0.784 mg/1.

C. NUTRIENT CONCENTRATIONS - 1969

Nutrient concentrations in the July and August 1969 surveys corroborate the findings in 1966 (presented in Appendix A). The nutrient concentrations for July 21-22, 1969, were the highest in the Opequon, Antietam, and Monocacy sub-basins (Figure X-1). Stream flow from the upper basin, including the North and South branches, diluted the runoff containing the high nutrient levels from the lower sub-basins.

Stations with high nutrient levels for selected watersheds are presented below:

Station	Stream	Location
A-3	Antietam Creek	below Hagerstown, Md.
MR-9	Little Pipe-Monocacy River	near confluence with Monocacy
MR-10	Monocacy River	below Md.-Pa. State Line
O-1	Abrams Creek-Opequon Creek	below Winchester, Va.
O-7	Tuscarora Creek-Opequon Ck.	below Martinsburg, W. Va.
S-4A	South River-South Fork Shenandoah River	below Waynesboro, Va.
S-8	Grassy Creek-South Fork Shenandoah River	below Harrisonburg, Va.

Numerous other stations in the Monocacy sub-basin also had high nutrient concentrations. During this survey, rainfall was fairly heavy throughout the watershed.

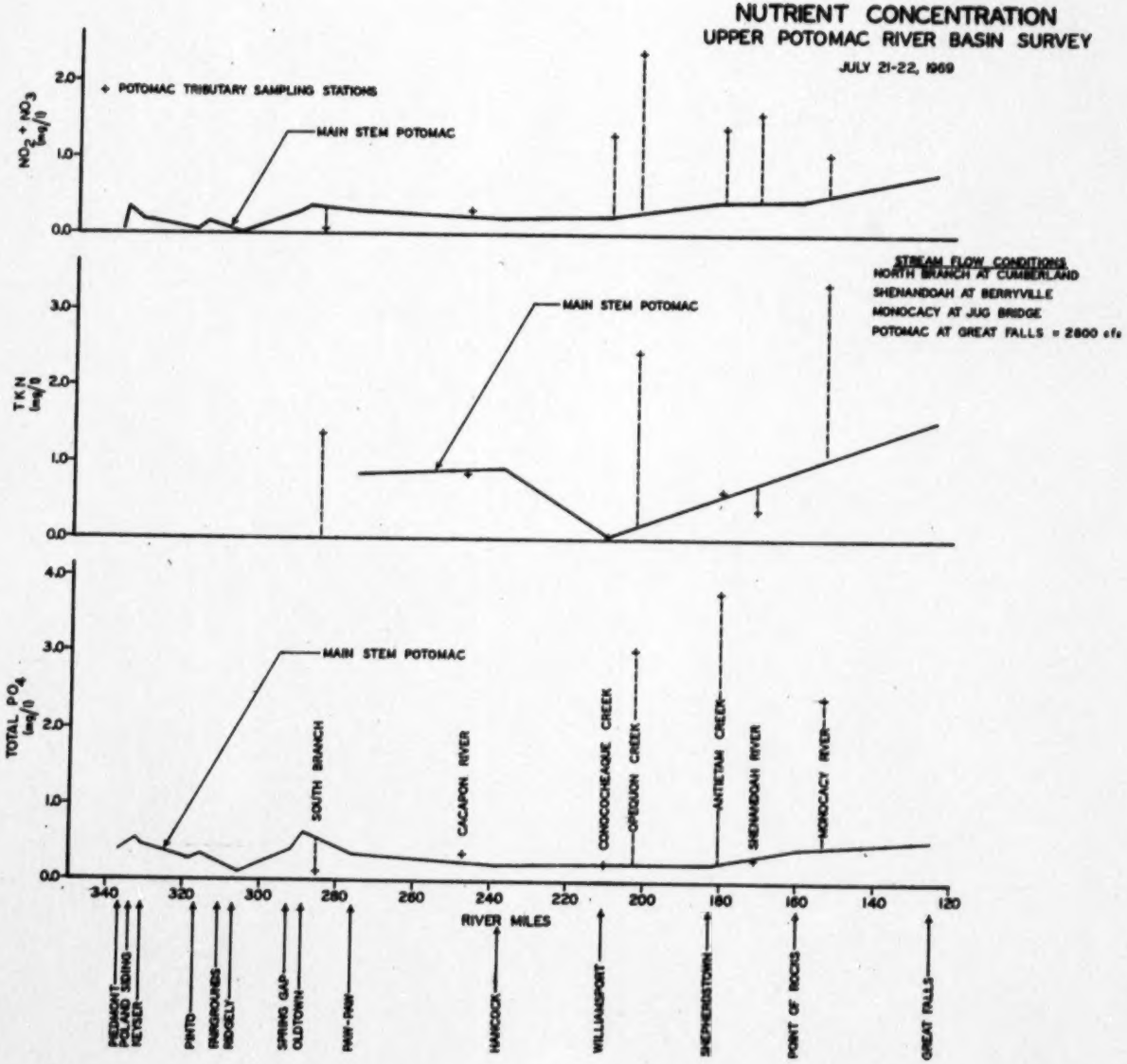

NUTRIENT CONCENTRATION
UPPER POTOMAC RIVER BASIN SURVEY
JULY 21-22, 1969
+ POTOMAC TRIBUTARY SAMPLING STATIONS
MAIN STEM POTOMAC
$NO_2 + NO_3$ (mg/l)
TKN (mg/l)
TOTAL PO_4 (mg/l)
STREAM FLOW CONDITIONS
NORTH BRANCH AT CUMBERLAND
SHENANDOAH AT BERRYVILLE
MONOCACY AT JUG BRIDGE
POTOMAC AT GREAT FALLS = 2800 cfs
SOUTH BRANCH
CACAPON RIVER
CONOCOCHEAGUE CREEK
OPEQUON CREEK
ANTIETAM CREEK
SHENANDOAH RIVER
MONOCACY RIVER
RIVER MILES
PIEDMONT
POLAND SPRING
RETSER
PINTO
ENGLEHOUNDS
RIDGELY
SPRING GAP
OLDTOWN
PAW-PAW
HANCOCK
WILLIAMSPORT
SHEPHERDSTOWN
POINT OF ROCKS
GREAT FALLS

FIGURE X-1

X-8

For the August 17-18, 1969 survey, the concentration of nutrients was also highest in the Opequon, Antietam, and Monocacy sub-basins (Figure X-2). Although the base streamflow was higher than during the July survey, the rainfall prior to the survey was less.

Sampling stations with high nutrient levels for selected sub-basins in the August survey are summarized below:

Station	Stream	Location
A-3	Antietam Creek	below Hagerstown, Md.
A-8	Antietam Creek	below Waynesboro, Pa.
C-13	Conococheague Creek	below Chambersburg, Pa.
MR-9	Little Pipe-Monocacy River	near confluence with Monocacy
MR-12	Rock Creek-Monocacy River	below Gettysburg, Pa.
O-1	Abrams Creek-Opequon Creek	below Winchester, Va.
O-7	Tuscarora Creek-Opequon Creek	below Martinsburg, W. Va.
S-8	Grassy Creek-South Fork-Shenandoah River	below Harrisonburg, Va.

D. EFFECTS IN THE UPPER BASIN

The data summarized in the tabulations indicate that high concentrations of nutrients, especially phosphorus and ammonia, result from municipal and industrial discharges. While the contribution from land runoff is significant, the most pronounced increases in nutrients are from point-source discharges.

Though the primary area of eutrophication is in the nutrient-rich Potomac Estuary, water supply treatment operational problems have occurred during periods of low flow for facilities on the main stem of the Potomac at Great Falls and on the Monocacy River. These problems

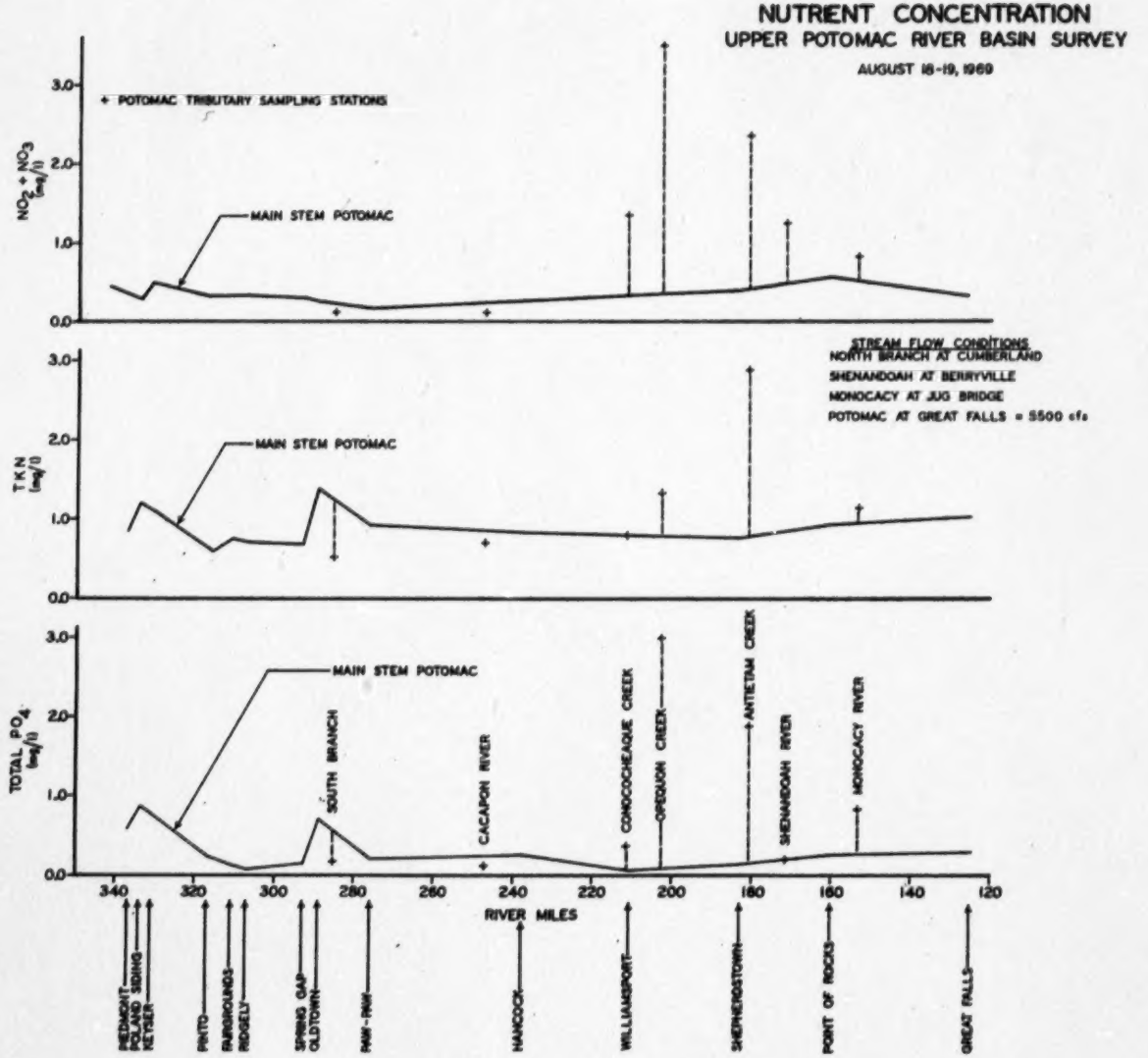

NUTRIENT CONCENTRATION
UPPER POTOMAC RIVER BASIN SURVEY
AUGUST 18-19, 1969
+ POTOMAC TRIBUTARY SAMPLING STATIONS
$NO_2 + NO_3$ (mg/l)
MAIN STEM POTOMAC
STREAM FLOW CONDITIONS
NORTH BRANCH AT CUMBERLAND
SHENANDOAH AT BERRYVILLE
MONOCACY AT JUG BRIDGE
POTOMAC AT GREAT FALLS = 5500 cfs
T.K.N (mg/l)
TOTAL PO_4 (mg/l)
SOUTH BRANCH
CACAPON RIVER
CONOCOCHEAGUE CREEK
OPEQUON CREEK
ANTIETAM CREEK
SHENANDOAH RIVER
MONOCACY RIVER
RIVER MILES
PIEDMONT
POLAND SPRING
KETNER
PINTO
RUMSEY
RIDGELY
SPRING GAP
OLDTOWN
MW - PAW
HANCOCK
WILLIAMSPORT
SHEPHERDSTOWN
POINT OF ROCKS
GREAT FALLS

FIGURE X-2

are mainly associated with phytoplankton growths. High growths as measured by chlorophyll "a" were observed during the August 1969 survey in the Monocacy and along the main stem of the Potomac.

Heavy rooted aquatic growths are common in the Opequon, Monocacy, Conococheague, and Antietam watersheds. These sub-basins are rich in nutrients originating both from land runoff and wastewater discharges.

In determining the magnitude of the eutrophication problem in the free-flowing upper basin streams, it has been established that the large rooted aquatic and phytoplankton growth occurs during low flow periods. During these periods, the major source of nutrients is from wastewater discharges.

At higher flows, the transport of nutrients is greatly increased and their effect in accelerating eutrophication is reduced. Thus it appears that the most significant cause of eutrophication is the controllable point-source waste loadings.

E. EFFECTS ON THE ESTUARY

Based on regression analysis equations from 1966 nutrient network data, the average monthly nutrient loadings at Great Falls computed for the average flow year were 21,200; 8,200; and 72,000 lbs/day of total phosphorus as PO_4; TKN; and NO_2 + NO_3 nitrogen, respectively [8]. The daily variation in nutrient loading is quite pronounced and is a function of streamflow. During the month of August 1966, less than 1,000 lbs/day of total phosphorus as PO_4 and NO_2 + NO_3 as N entered the upper estuary from the upper basin while

on February 14, 1966, about 217,000 and 354,000 lbs/day of PO_4 and $NO_2 + NO_3$, respectively, entered the estuary.

The streamflow hydrography of the Potomac at Great Falls for the first eight months of 1969 was not typical. The flows were at a record low for the month of June with high flows occurring in August (Figure X-3).

Since the river discharge distribution was not typical, the nutrient loadings into the estuary for the first eight months of 1969 were also non-typical. As can be seen in Figures X-3 and X-4, the total phosphorus TKN, $NO_2 + NO_3$ loadings from February through July were usually less than 10,000 lbs/day. This contrasted with about 63,000 and 54,000 lbs/day of total phosphorus and nitrogen, respectively, from wastewater discharges in tidal waters of the Potomac Estuary.

During part of July and in August, the nutrient contributions increased tremendously due to the increase in river discharge. Even at the high flows, the contribution of phosphorus was greater from the wastewater discharges in the Washington area than from all sources in the upper basin.

To aid in the Potomac Estuary nutrient transport study, the forms of the various nutrients are also being distinguished. Figure X-3 shows that only about 25 percent of the total phosphorus is in the dissolved reactive form. This indicates that most of the phosphorus in the upper basin is or becomes attached to silt particles and can be removed by settling such as behind a small dam or in the estuary.

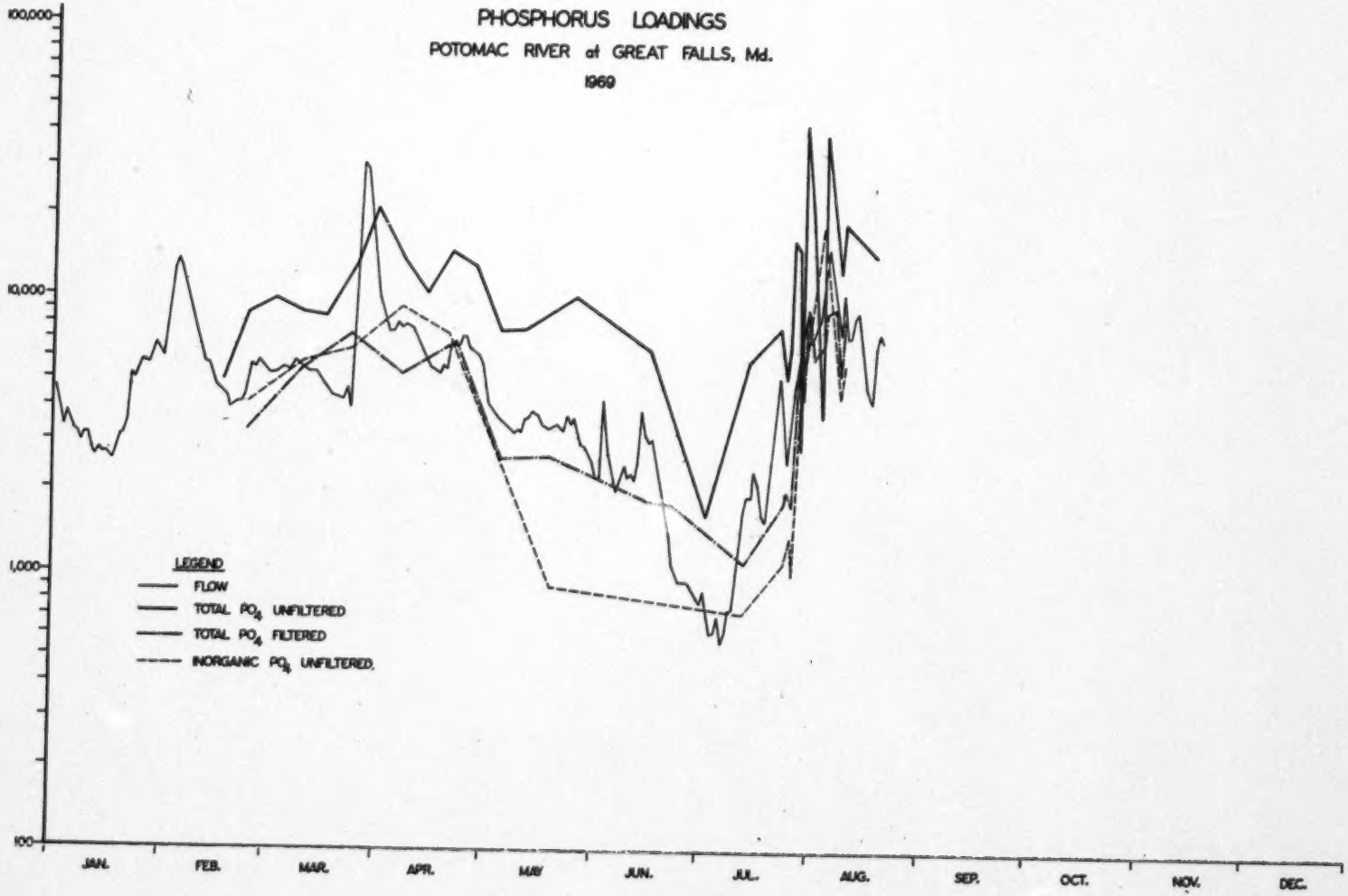

PHOSPHORUS LOADINGS
POTOMAC RIVER at GREAT FALLS, Md.
1969
100,000
10,000
1,000
100
LEGEND
FLOW
TOTAL PO_4 UNFILTERED
TOTAL PO_4 FILTERED
INORGANIC PO_4 UNFILTERED
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.

FIGURE X-3

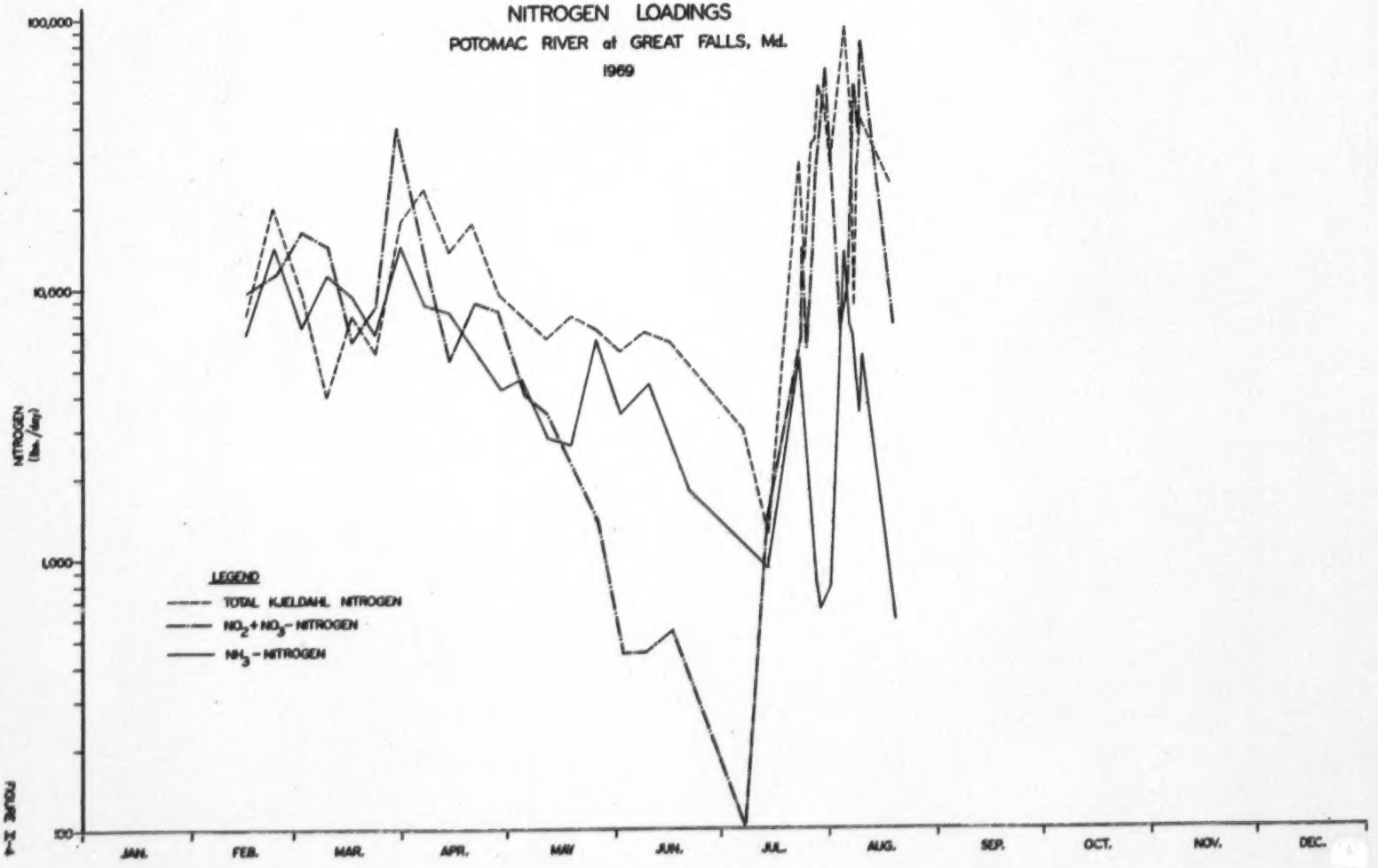

NITROGEN LOADINGS
POTOMAC RIVER at GREAT FALLS, Md.
1969
100,000
10,000
1,000
100
NITROGEN (lbs./day)
LEGEND
TOTAL KJELDAHL NITROGEN
$NO_2 + NO_3$ - NITROGEN
NH_3 - NITROGEN
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.

FIGURE X-4

Fraction studies of the TKN form indicate that over 50 percent is in the particulate form also subject to settling when the conditions are suitable.

APPENDIX

DATA SUMMARIES

APPENDIX

Table	Description
A-1	North Branch Potomac July 1969
A-2	North Branch Potomac August 1969
A-3	South Branch Potomac July 1969
A-4	South Branch Potomac August 1969
A-5	Conococheague Creek July 1969
A-6	Conococheague Creek August 1969
A-7	Antietam Creek July 1969
A-8	Antietam Creek August 1969
A-9	Opequon Creek July 1969
A-10	Opequon Creek August 1969
A-11	North Fork and Main Stem Shenandoah July 1969
A-12	North Fork and Main Stem Shenandoah August 1969
A-13	South Fork Shenandoah July 1969
A-14	South Fork Shenandoah August 1969
A-15	Monocacy River July 1969
A-16	Monocacy River August 1969
A-17	Potomac River July 1969
A-18	Potomac River August 1969
A-19	Upper Potomac Bacteriological Study July through September 1966

TABLE A-1
NORTH BRANCH POTOMAC
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	pH	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	NO_2+NO_3 mg/l NO_3-N	NH_3 mg/l-N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l	Fe_2+Fe_3 mg/l	Acidity mg/l
69072948	7-28	1135	Sta NB 3	24.5	2.9	LA	LA	ND	.050	.135	28.50	4.5	7.79	0.80	1.75	130.95
49		1150	NB 4	31.0	8.4	LA	LA	.901	.121	.372	3.75	50.0	.07	5.99	ND	6.79
50		1115	NB 5	22.0	3.95	8,100	2,400	.396	.323	.205		55.0	7.83	2.48	ND	67.9
51		1100	NB 6	29.5	6.9	160,900	91,800	.552	.110	.201		65.0	.17	13.76	.635	13.095
52		1220	NB 7	30	6.55	3,480	3,480	.468	.060	.180		65.0	.93	14.10	.580	6.79
53		1030	NB10	26	6.7	9,180	9,180	.886	.070	.194		45.0	4.58	5.52	.600	
54		1000	NB11	28	6.2	160,900	91,800	.333	.148	.340	7.50	40.0	1.69	15.40	.10	
55		0915	NB12	29	6.35	54,200	54,200	.094	.005	.322	9.00	15.0	.59	12.92	ND	
56		1835	NB19	28		9,400	10,090	.442	.229	.415	10.50	9.0	4.47	4.34	ND	
57		1820	NB20	28.5		5,420	5,420	.631	.360	.252	10.50	10.0	5.50	4.43	ND	

NB 3 - North Branch Potomac - Headwater of West Virginia Pulp and Paper Company, Luke Mill Impoundment.
NB 4 - North Branch Potomac - Bridge between Luke, Maryland and Piedmont, West Virginia.
NB 5 - Georges Creek - Bridge in Westernport, Maryland.
NB 6 - North Branch Potomac - Off Maryland Route 135, five miles east of Westernport High School.
NB 7 - North Branch Potomac - U.S. Route 220 Bridge between McCoole, Maryland and Keyser, West Virginia.
NB10 - North Branch Potomac - Bridge between Pinto, Maryland and Short Gap, West Virginia.
NB11 - North Branch Potomac - Cumberland Fair Grounds.
NB12 - North Branch Potomac - Bridge on West Virginia Route 28 between Cumberland, Maryland and Ridgley, West Virginia.
NB19 - North Branch Potomac - Spring Gap.
NB20 - Potomac River - One mile south of Oldtown, West Virginia.

LA - Laboratory accident.
ND - Not detectable

TABLE A-2
NORTH BRANCH POTOMAC
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	pH	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chlorophyll a ug/l	Turbidity JTU	DO mg/l	BOD mg/l
69081902	8-18	1145	Sta NB 3	23	3.00	60	20	1.305	1.130	.304	.106	5.25	75	7.92	2.78
03		1200	NB 4	25	3.25	56	LA	1.131	.914	.292	.208	3.75	80	5.74	6.10
04		1130	NB 5	23	4.25	< 20	< 20	.609	.859	.450	.172	1.50	20	7.96	3.44
05		1115	NB 6	26	3.75	9,180	1,090	.868	1.193	.280	.171	2.25	35	4.67	10.54
06		1220	NB 7	26.5	4.10	91,800	LA	.811	1.117	.249	.030	0	75	3.14	7.28
07		1040	NB10	25	3.65	1,090	110	.251	.597	.311	.053	2.25	35	6.08	3.22
08		1010	NB11	26	3.30	170	50	.132	.749	.302	.226	3.74	3	5.49	15.40
09		0945	NB12	25	3.60	170	LA	.074	.698	.331	.058	.75	2	6.98	4.16
10		1715	NB19	25		22,100	LA	.129	.673	.301	.205	3.00	6	6.68	3.02
11		1655	NB20	25.5		1,720	LA	.720	1.460	.249	.236	3.00	45	6.50	NSL

NB 3 - North Branch Potomac - Headwater of West Virginia Pulp and Paper Company, Luke Mill Impoundment.
NB 4 - North Branch Potomac - Bridge between Luke, Maryland and Piedmont, West Virginia.
NB 5 - Georges Creek - Bridge in Westernport, Maryland.
NB 6 - North Branch Potomac - Off Maryland Route 135, five miles east of Westernport High School.
NB 7 - North Branch Potomac - U.S. Route 220 Bridge between McCoole, Maryland and Keyser, West Virginia.
NB10 - North Branch Potomac - Bridge between Pinto, Maryland, and Short Gap, West Virginia.
NB11 - North Branch Potomac - Cumberland Fair Grounds.
NB12 - North Branch Potomac - Bridge on W. Va. Route 28 between Cumberland, Md. and Ridgley, W. Virginia.
NB19 - North Branch Potomac - Spring Gap.
NB20 - Potomac River - 1 mile south of Oldtown, West Virginia.

LA - Laboratory accident
NSL- No sample left

TABLE A-3

SOUTH BRANCH POTOMAC
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l	Chlorophyll a ug/l	Turbidity JTU	DO mg/l	BOD mg/l
69073023	7-29	1110	Sta SB1		1,090	700	.074	LA	..17	.060	2.25	6.0	8.24	2.99
24		1110	SB2		54,200	54,200	.144	.730	.100	.107	6.00	6.5	8.16	2.90
25		1110	SB3		2,700	200	.031	.399	.006	.070	2.25	2.0	8.59	3.03
26		1110	SB4		9,400	7,000	.028	.521	.015	.045	2.25	1.5	8.44	2.92
27		1110	SB5		34,800	34,800	.221	.423	.140	.051	6.00	50.0	7.05	2.60
28		1110	SB6		2,210	LA	.126	.706	.193	.088	13.50	6.6	7.83	3.22
29		1110	SB9		170	490	.105	1.391	.065	.036	7.50	2.5	9.07	3.28

SB1- South Branch Potomac, Route 220, South Petersburg, West Virginia.

SB2- South Branch Potomac, Route 220, West Petersburg & South Rig, West Virginia.

SB3- South Fork Branch Potomac, 6 miles south of Moorefield, West Virginia.

SB4- South Fork Branch Potomac, Intersection U. S. Route 220, 1 mile SSW of Moorefield, West Virginia.

SB5- South Branch Potomac, Intersection U. S. Route 220, 3 miles south of Old Fields, West Virginia.

SB6- South Branch Potomac, Intersection U. S. Route 50, 5 miles west of Romney, West Virginia.

SB9- South Branch Potomac, 2½ miles west of Points, West Virginia.

LA- Laboratory Accident.

TABLE A-4

SOUTH BRANCH POTOMAC
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chlorophyll a ug/l	Turbidity JTU	DO mg/l	BOD mg/l
69081912	8-18	1450	Sta SB1	23.0	17,200	LA	.170	.487	.060	.030	1.50	8.5	8.01	NSL
13		1435	SB2	23.5	13,000	13,000	.202	.749	.129	.019	6.75	25.0	7.76	NSL
14		1355	SB3	24.0	1,090	170	.068	.381	.260	.033	7.50	6.0	8.16	3.48
15		1415	SB4	24.5	4,600	1,100	.106	1.371	.244	.046	7.50	4.0	7.80	3.53
16		1335	SB5	26.0	54,200	54,200	.133	.902	.131	.083	3.75	6.0	7.93	6.56
17		1600	SB6	25.0	3,480	1,720	.182	.635	.142	.017	3.75	3.5	7.73	3.95
18		1630	SB9	26.0	1,720	370	.185	.521	.135	.047	7.50	3.5	8.34	5.04

SB1 - South Branch Potomac-------- Route 220, South Petersburg, West Virginia

SB2 - South Branch Potomac-------- Route 220, West Petersburg and South of Rig, West Virginia

SB3 - South Fork Branch Potomac--- Six miles south of Moorefield, West Virginia

SB4 - South Fork Branch Potomac--- Intersection U. S. Route 220, one mile SSW of Moorefield, West Virginia

SB5 - South Branch Potomac-------- Intersection U. S. Route 220, three miles south of Old Fields, West Virginia

SB6 - South Branch Potomac-------- Intersection U. S. Route 50, five miles west of Romney, West Virginia

SB9 - South Branch Potomac-------- Two and one half miles west of Points, West Virginia

LA - Laboratory Accident

NSL - No Sample Left

TABLE A-5

CONOCOCHEAGUE CREEK
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P $\mu g/l$ PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69072938	7-28	1315	Sta C- 3	24.5	3,480	700	.504	.853	1.31	.100	7.50	24.0	5.86	3.44
39		1240	C- 4	22.5	> 160,900	> 160,900	.850	2.641	1.66	.158		52.0	5.78	7.35
40		1220	C- 6	23	IA	34,800	.279	.871	0.95	.127	4.50	45.0	6.95	2.92
41		1150	C- 7	22.5	91,800	91,800	.334	2.494	0.58	.115		45.0	6.18	5.13
42		1105	C- 8	22.5	54,200	13,000	.278	2.141	0.55	.074		50.0	6.29	5.24
43		1035	C-10	22	> 160,900	91,800	1.072	1.841	1.59	.196	14.25	60.0	6.24	5.51
44		1010	C-11	22	160,900	54,200	1.691	1.441	1.71	.188		65.0	6.01	5.77
45		0945	C-12	21.5	54,200	13,000	.890	1.553	1.67	.206		60.0	6.21	4.23
46		0915	C-13	21	> 160,900	91,800	1.266	1.382	1.54	.175		65.0	6.39	4.76
47		0825	C-14	21	> 160,900	160,900	.993	1.335	0.87	.169		70.0	7.30	4.20

C- 3 - Conococheague Creek - Kempé Mill Road Bridge.
C- 4 - Conococheague Creek - Md. Route 58 Bridge.
C- 6 - Conococheague West Branch - West Bridge above Welsh.
C- 7 - Conococheague West Branch - Pa. Route 16.
C- 8 - Conococheague West Branch - Oregon Street Bridge.
C-10 - Conococheague Creek - Pa. Route 16.
C-11 - Conococheague Creek - Bridge above Williamson.
C-12 - Conococheague Creek - Tallow Hill Road Bridge.
C-13 - Conococheague Creek - Honeywell Road.
C-14 - Conococheague Creek - Pa. Route 30.

IA - Laboratory accident

TABLE A-6

CONOCOCHEAGUE CREEK
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
9081958	8-18	1055	Sta C 3	26	9,180	1,750	.374	.800	1.36	.065	11.25	15	7.23	3.10
59		1115	C 4	24.5	34,800	1,300	.482	.787	1.68	.029	9.75	45	9.25	2.53
60		1135	C 6	25	9,400	700	.114	.444	.673	.040	5.25	1.5	9.46	2.23
61		1230	C 7	24.5	5,420	5,420	.152	.990	.510	.065	18.75	7	11.37	4.46
62		1245	C 8	25	LA	LA	.046	.355	.240	.023	9.75	1.5	11.33	1.26
63		1315	C10	25	9,180	2,400	.910	.660	2.24	.050	7.50	2	8.94	2.06
64		1345	C11	24.0	9,180	3,480	1.144	.914	3.25	.028	4.50	4.5	8.20	3.70
65		1405	C12	23.0	34,800	7,000	1.217	.724	3.70	.073	5.25	3	7.79	3.12
66		1420	C13	23	160,900	22,100	1.976	.978	3.48	.135	4.50	15	5.79	5.37
67		1450	C14	22.5	>160,900	>160,900	.563	1.435	1.38	.118	18.00	60	6.83	7.26

C 3 - Conococheague Creek - Kemps Mill Road Bridge.
C 4 - Conococheague Creek - Md. Route 58 Bridge.
C 5 - Conococheague West Branch - West Bridge above Welsh.
C 7 - Conococheague West Branch - Pa. Route 16.
C 8 - Conococheague West Branch - Oregon Street Bridge.
C10 - Conococheague Creek - Pa. Route 16.
C11 - Conococheague Creek - Bridge above Williamson.
C12 - Conococheague Creek - Tallow Hill Road Bridge.
C13 - Conococheague Creek - Honeywell Road.
C14 - Conococheague Creek - Pa. Route 30.

LA - Laboratory accident

TABLE A-7

ANTIETAM CREEK
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69072933	7-28	1650	Sta A1		>160,900	91,500	3.803		1.91	.662	25.50	45.0	4.01	7.44
34		1600	A2	25	>160,900	54,200	2.721		2.22	.275		50.0	6.03	7.58
35		1500	A3	24.5	>160,900	160,900	8.342		1.52	.740		11.0	5.81	LA
36		1430	A4	22.2	>160,900	>160,900	2.933		1.55	.299		50.0	6.61	7.42
69073937	7-29	1200	A5	19	91,800	91,800	.574	.971	1.57	.078	37.50	23.5	6.99	2.92
38		1220	A7	19	54,200	10,900	.554	1.059	1.58	.234	10.50	8.5	7.86	2.98
39		1230	A8	19	>160,900	1,400	.956	.988	1.25	.250	13.50	8.5	7.90	2.74
40		1255	A9	19	17,200	1,400	.335	.635	1.14	.047	2.25	25.0	8.35	1.45

A1 - Antietam Creek - Burnside Bridge Gaging Station
A2 - Antietam Creek - Md. Route 68 Bridge
A3 - Antietam Creek - Rench Road Bridge
A4 - Antietam Creek - U.S. 40 Bridge
A5 - Antietam Creek - Old Forge Road Bridge
A7 - Antietam Creek - Off Md. Route 60 near Rocky Forge
A8 - Antietam Creek - Md. Route 60 - Pa. Route 316 Bridge
A9 - Antietam Creek - Md. Route 64 - Pa. Route 997 Bridge

LA - Laboratory accident

TABLE A-8

ANTIETAM CREEK
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69081950	8-18	0930	Sta A1	24	54,200	24,000	1.924	2.959	2.34	.053	8.25	45	6.06	4.09
51		0904	A2	24.5	4,900	4,900	2.880	1.371	3.00	ND	11.25	15	6.76	MSL
52		0830	A3	26.0	91,800	91,800	2.464	2.361	2.24	1.47	6.00	3	4.01	>7.32
53		1645	A4	23.0	> 160,900	> 160,900	.827	2.375	2.25	.077	15.00	200	7.09	2.87
54		1615	A5	22	160,900	160,900	.885	.775	1.65	.113	1.50	150	6.71	4.59
55		1600	A7	22.0	> 160,900	34,800	1.522	2.400	1.76	.98	42.00	40	6.70	>7.91
56		1555	A8	22	> 160,900	160,900	3.223	3.200	.89	1.35	19.50	85	5.84	>7.72
57		1545	A9	22.0	> 160,900	160,900	.995	2.006	.60	.113	33.00	200	6.76	5.85

A1 - Antietam Creek - Burnside Bridge Gaging Station.
A2 - Antietam Creek - Md. 68 Bridge.
A3 - Antietam Creek - Rench Road Bridge.
A4 - Antietam Creek - U.S. 40 Bridge.
A5 - Antietam Creek - Old Forge Road Bridge.
A7 - Antietam Creek - Off Md. 60 Near Rocky Forge.
A8 - Antietam Creek - Md. 60 - Pa. 316 Bridge.
A9 - Antietam Creek - Md. 64 - Pa. 997 Bridge.

LA- Laboratory Accident.

TABLE A-9
OPEQUON CREEK
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3-N	NH_3 mg/l-N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69073001	7-29	0755	Sta 01	21	34,800	7,900	3.044	2.466	2.35	.093	4.90	10.0	6.38	2.97
02		0740	02	22	34,800	34,800	.168	.791	0.430	.056	6.75	30.0	6.29	2.96
03		0825	03	22	54,200	17,200	.912	.816	.89	.038	10.50	30.0	6.50	3.00
04		0855	04	23	17,200	4,900	1.516	.988	2.00	.080	11.25	49.0	6.48	3.68
05		0920	05	22	4,900	3,300	1.445	1.012	1.90	.066	16.50	45.0	6.35	3.06
06		0940	06	23	4,900	700	1.471	.706	2.80	.070	8.25	25.0	6.39	2.74
07		1000	07	20	7,900	0	5.520	1.939	>3.00	.605	17.25	70.0	5.63	5.77
08		1015	08	22.5	7,900	4,900	1.462	.607	2.03	.074	8.25	30.0	6.38	2.55
09		1045	09	23	4,900	3,300	1.669	.571	2.27	.056	6.75	25.0	6.26	2.29

01 - Abrams Creek - Lefthand cutoff 1/2 mile west of Station O-2 Bridge.
02 - Opequon Creek - Route 7 Bridge.
03 - Opequon Creek - Va. Route 761 deadend, north on Route 11.
04 - Opequon Creek - Va. Route 51 Bridge.
05 - Opequon Creek - Leetown to Danville Road Bridge, turn left on Route 48.
06 - Opequon Creek - Va. Route 9 Bridge Gaging Station.
07 - Tuscarora Creek - Rosedale Cemetary Road Bridge.
08 - Opequon Creek - West Virginia Route 45 Bridge.
09 - Opequon Creek - Lights Ford Bridge.

TABLE A-10.

OPEQUON CREEK
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69082001	8-19	0810	Sta 01	20	> 160,900	> 160,900	3.031	1.371	3.48	.413	5.25	4.5	5.80	5.52
02		0800	02	21.5	91,800	> 24,000	.159	.889	.64	.037	5.25	25	6.44	3.89
03		0840	03	21	> 160,900	> 24,000	1.078	.508	1.46	.049	9.25	15	6.43	4.25
04		0905	04	20.5	34,800	13,000	.626	.686	2.40	.005	6.00	12.5	7.35	3.24
05		0935	05	21	34,800	2,700	.800	.533	1.98	.044	10.50	20	6.90	3.40
06		1000	06	21	54,200	4,700	.998	.851	1.39	.067	3.75	35	6.71	4.26
07		1030	07	19.5	17,200	LA	2.033	.952	3.75	.219	12.75	30	6.27	5.53
08		1045	08	21	7,200	13,000	.943	.851	1.36	.067	6.75	40	6.57	4.37
09		1115	09	21.5	160,900	17,200	1.035	.295	1.49	.067	7.50	60	6.63	5.09

01 - Abrams Creek - Lefthand cutoff 1/2 mile west of Station 0-2 Bridge.
02 - Opequon Creek - Route 7 Bridge.
03 - Opequon Creek - Va. Route 761 Deadend, north on Route 11.
04 - Opequon Creek - Va. Route 51 Bridge.
05 - Opequon Creek - Leetown to Danville Road Bridge, turn left on 48.
06 - Opequon Creek - Va. Route 9 Bridge Gaging Station.
07 - Tuscarora Creek - Rosedale Cemetary Road Bridge.
08 - Opequon Creek - West Virginia. Route 45 Bridge.
09 - Opequon Creek - Lights Ford Bridge.

LA - Laboratory accident

TABLE A-11

NORTH FORK AND MAIN STEM SHENANDOAH
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2 + NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69073012	7-29	1505	Sta N1	24	2,600	3,100	.039	.202	0.71	.038	6.00	4.0	9.48	1.74
13		1515	N1A	22	3,300	3,300	.059	.368	1.48	.030	3.00	5.0	9.54	1.03
14		1440	N2	23	54,200	54,200	.599	1.129	2.19	.412	8.25	35.0	7.36	4.02
15		1425	N2A	25	54,200	54,200	.683	.791	2.17	.130	9.75	70.0	6.67	3.35
16		1345	N2B	22	160,900	91,800	1.450	1.018	1.50	.252	30.75		4.41	6.17
17		1355	N3	23.5	LA	LA	.975	1.294	1.86	.148	16.50	15.0	5.86	3.98
18		1320	N3A	23	54,200	54,200	.253	.798	0.58	.075	15.00	75.0	7.29	2.96
19		1305	N3B	23	54,200	54,200	.896	1.209	1.57	.103	11.25	15.0	6.34	3.40
20		1230	N4	24.5	3,900	14,100	.366	.644	1.67	.100	15.00	50.0	7.36	2.40
21		1125	N5	25	7,000	13,000	.408	.945	1.48	.064	6.75	29.0	5.99	2.15
22		1110	N6	25	10,900	4,900	.310	.840	1.39	.081	7.50	15.0	6.24	1.83
69073033		1730	M1	24	17,200	13,000	.530	1.241	1.09	.185	4.50		5.24	4.55
34		1610	M1A	25	4,900	3,300	.521	.982	1.48	.188	18.75	28.0	5.16	2.62
35		1540	M2	26	2,400	1,300	.514	1.141	1.51	.120	12.00	25.0	5.35	2.30
36		1455	M3	25	2,400	330	.314	1.406	1.62	.112	8.25	19.0	6.04	4.29

N1 - North Fork Shenandoah - Route 259 Bridge near Cootes Store
N1A- North Fork Shenandoah - Bridge off Route 259 in Broadway
N2 - " " " " - Route 42 Bridge in Timberville
N2A- " " " " - Bridge off Route 260 near New Market
N2B- Smith Creek - Bridge off U. S. Route 11 about 0.5 miles north of Rudes Hill
North Fork Shenandoah - Route 767 Bridge east of Quicksburg
N3A- Stony River - Bridge of U. S. Route 11 in Edinburg
N3B- North Fork Shenandoah - Bridge off Route 11 two miles below Edinburg
N4 - " " " " - Route 663 Bridge northeast of Woodstock
N5 - " " " " - Route 55 Bridge east of Strasburg
N6 - " " " " - U. S. Route 340 Bridge in Front Royal

M1 - Main Stem Shenandoah - Route 624 Bridge north of Front Royal
M1A- " " " " - U. S. Route 50 Bridge
M2 - " " " " - Route 7 Bridge east of Berryville
M3 - " " " " - Route 9 Bridge east of Bloomery

LA - Laboratory Accident

TABLE A-12

NORTH FORK AND MAIN STEM SHENANDOAH
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3-N	NH_3 mg/l	Chlorophyll a ug l	Turbidity JTU	DO mg/l	BOD mg/l
69082010	8-19	1205	Sta N 1	21	9,180	940	.019	.203	2.07	.04	4.50	1.5	8.54	1.71
11		1215	N 1A	20.5	3,480	640	.035	.165	2.45	ND	3.00	2	9.13	2.04
12		1145	N 2	20.5	> 160,900	> 160,900	.191	.381	2.76	.33	11.25	1.5	7.47	3.26
13		1130	N 2A	21	> 160,900	13,000	.209	.521	2.92	.17	9.00	1.5	8.65	2.48
14		1045	N 2B	21	24,000	7,900	.071	.229	1.74	ND	9.75	6.5	7.51	1.73
15		1105	N 3	21.5	24,000	7,900	.136	.127	2.88	.05	15.00	1.0	7.20	2.20
16		1000	N 3A	21.0	7,900	> 2,300	.125	.102	1.74	ND	9.00	2.5	8.01	1.65
17		1030	N 3B	21.5	160,900	1,700	.111	LA	2.26	ND	2.25	2	7.61	1.92
18		0935	N 4	22.5	2,210	130	.103	LA	1.88	ND	5.25	2.5	8.15	1.84
19		0855	N 5	23	3,480	790	.134	LA	1.77	ND	4.50	5	7.24	1.76
20		0835	N 6	24	2,300	500	.139	LA	1.52	ND	5.25	2.5	7.47	1.70
69082023	8-19	1130	M 1	25.5	4,900	1,700	.324	LA	1.40	.10	9.00	3	6.65	4.23
24		1105	M 1A	24.5	2,300	1,300	.297	LA	1.34	.07	2.25	3.5	5.79	3.15
25		1030	M 2	25.0	LA	LA	.255	LA	1.30	ND	45.00	5.5	6.72	2.94
26		1000	M 3	25	54,200	33,000	.229	LA	1.25	.06	33.00	4.5	6.47	3.34

N1 - North Fork Shenandoah - Route 259 Bridge near Cootes Store.
N1A- North Fork Shenandoah - Bridge off Route 259 in Broadway
N2 - North Fork Shenandoah - Route 42 Bridge in Timberville.
N2A- North Fork Shenandoah - Bridge off Route 260 near New Market.
N2B- Smith Creek - Bridge off U.S. Route 11 about 0.5 miles north of Rudes Hill.
N3 - North Fork Shenandoah - Route 767 Bridge east of Quicksburg.
N3A- Stony River - Bridge off U.S. Route 11 in Edinburg.
N3B- North Fork Shenandoah - Bridge off U.S. Route 11 two miles below Edinburg.
N4 - North Fork Shenandoah - Route 663 Bridge northeast of Woodstock.
N5 - North Fork Shenandoah - Route 55 Bridge east of Strasburg.
N6 - North Fork Shenandoah - Route 340 Bridge in Front Royal.

M1 - Main Stem Shenandoah - Route 624 Bridge north of Front Royal.
M1A-Main Stem Shenandoah - Route 50 Bridge
M2 - Main Stem Shenandoah - Route 7 Bridge east of Berryville.
M3 - Main Stem Shenandoah - Route 9 Bridge east of Bloomery.

LA - Laboratory accident
ND - Not detectable

TABLE A-13

SOUTH FORK SHENANDOAH
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l	NO_2+NO_3 mg/l NO_3-N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69081920	8-18	1345	Sta S 1	23	54,200	34,800	.128	.711	.88	.226	6.75	35	8.06	2.02
21		1410	S 3	23	14,100	LA	.719	2.260	1.91	1.03	4.50	20	2.83	6.49
22		1425	S 3A	23	7,000	LA	.578	.775	2.23	.050	3.75	10	5.29	2.21
23		1300	S 4	23	17,500	2,100	.598	.876	1.83	.052	15.00	30	6.52	2.07
24		1245	S 4A	22.5	10,900	3,480	.455	.559	1.37	.073	7.50	30	7.45	1.68
25		1445	S 6	23	91,800	160,900	.605	1.003	.80	.073	6.75	50	6.81	2.90
26		1505	S 6A	23	34,800	2,400	.583	.749	1.14	.047	11.25	24	7.30	3.29
27		1545	S 8	21.5	91,800	91,800	1.678	1.727	4.8	.960	6.75	40	5.88	7.86
28		1535	S 9	21.5	13,000	LA	.128	.584	1.38	.052	4.50	4	8.55	2.00
29		1520	S 9B	21.5	24,000	LA	.305	.622	1.72	.024	6.75	60	7.81	1.97
30		1315	S10	23	17,200	10,900	.517	.736	1.42	.029	12.00	25	7.34	1.81
31		1215	S11	22.5	7,000	LA	.530	.724	1.47	.030	12.00	25	7.30	2.74
32		1130	S12	23	34,800	13,000	1.022	1.156	1.53	.359	15.00	35	6.13	4.31
33		1110	S13	24	13,000	7,900	.797	1.219	1.70	.310	6.75	20	5.62	2.73
34		1030	S14	25	2,600	LA	.578	LA	1.52	.010	15.00	15	7.46	1.29
35		1000	S15	22	3,300	3,300	.080	.571	.54	.035	3.00	2.5	7.35	1.09
36		0945	S16	25	2,400	LA	.032	.711	.78	.029	3.75	2	9.19	.47
69082021		0800	S19	24.5	17,200	400	.441	LA	1.42	ND	6.00	8.5	6.63	1.63
22		0825	S20	25.0	2,210	170	.463	LA	1.38	.1	2.25	4.5	7.03	2.23

S 1 - South River - Chesnut Avenue Bridge in Waynesboro.
S 3 - South River - Route 611 Bridge near Coiners Mill.
S 3A- South River - Bridge in Harriston off U.S. Route 340.
S 4 - South River - Route 629 Bridge in Port Republic.
S 4A- Middle River - Route 629 Bridge in Port Republic.
S 6 - Middle River - Route 256 Bridge west of Grottoes.
S 6A- Middle River - Route 256 Bridge west of Grottoes.
S 8 - Grassy Creek (Black Run) - Route 867 Bridge east of Mt. Crawford.
S 9 - North River - U.S. Route 11 Bridge south of Mt. Crawford.
S 9B- North River - U.S. Route 276 Bridge in Rockland Mill.
S10 - South Fork Shenandoah - Route 659 Bridge north of Grottoes.
S11 - South Fork Shenandoah - Route 649 Bridge east of McGaheyville.
S12 - South Fork Shenandoah - U.S. Route 33 Bridge west of Elkton.
S13 - South Fork Shenandoah - Route 602 Bridge west of Shenandoah.
S14 - South Fork Shenandoah - Bixler Bridge.
S15 - Hawksbill Creek - Off U.S. Route 340 south of Luray.
S16 - Hawksbill Creek - Off U.S. Route 340 north of Luray.
S19 - South Fork Shenandoah - Luray Avenue Bridge in Front Royal.
S20 - South Fork Shenandoah - U.S. Route 340 Bridge in Front Royal.

LA - Laboratory accident
ND - Not detectable

TABLE A-14
SOUTH FORK SHENANDOAH
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l-N	NO_2+NO_3 mg/l NO_3-N	NH_3 mg/l-N	Chlorophyll a ug/l	Turbidity JTU	DO mg/l	BOD mg/l
69072901	7-28	1230	Sta S- 1	25	17,500	7,000	.105	.394	.690	.108	13.50	30.0	9.28	4.34
02		1335	S- 3	26.5	4,800	1,700	1.371	.418	.780	2.66	9.00	6.5	2.78	9.18
03		1400	S- 3A	25.5	9,180	1,720	1.036	1.323	1.67	.372	4.50	3.5	5.40	5.72
04		1205	S- 4	25	22,100	> 1,090	.685	.694	1.55	.013	9.75	8.5	7.73	4.00
05		1155	S- 4A	23	54,200	34,800	5.16	1.900	2.31	.115	15.75	70.0	6.57	4.37
06		1155	S- 6	26.5	22,100	71,090	.863	.676	1.21	.047	15.75	55.0	6.26	LA
07		1430	S- 6A	24.5	> 160,900	160,900	.941	1.746	1.94	.198	8.25	80.0	6.53	6.19
08		1540	S- 8	24.5	> 160,900	160,900	2.141	2.147	3.00	.404	6.75	70.0	5.43	8.31
09		1520	S- 9	23	> 160,900	> 160,900	.853	1.029	1.31	.128	10.50	65.0	6.92	4.87
10		1455	S- 9B	23	160,900	91,800	2.498	2.200	1.71	.220	17.25	75.0	6.65	7.77
11		1135	S-10	23.5	24,000	34,800	.797	1.065	2.00	.050	15.00	65.0	6.84	3.13
12		1105	S-11	24	4,900	3,300	.540	.729	1.97	.053	9.00	45.0	6.77	2.54
13		1040	S-12	23.5	24,000	34,800	.836	1.446	1.94	.443	6.00	50.0	5.02	5.75
14		1020	S-13	23.5	34,500	27,800	.972	1.047	2.06	.386	6.00	55.0	3.05	3.92
15		0925	S-14	25	1,090	1,300	.713	.759	2.10	.182	11.25	70.0	5.79	3.61
16		0940	S-15	21.5	17,200	13,000	.211	.376	.214	.012	4.50	4.0	7.22	1.72
17		0910	S-16	22	160,900	160,900	1.214	1.676	.840	1.48	6.00	4.5	3.42	5.04
69073010	7-29	1040	S-19	25	34,800	22,100	.559	.779	1.35	.044	9.75	33.0	6.03	2.86
11		1100	S-20	25	4,900	2,200	.643	1.104	1.39	.030	15.75	55.0	6.33	3.82

S 1 - South River - Chesnut Avenue Bridge in Waynesboro.
S 3 - South River - Route 611 Bridge near Coiners Mill.
S 3A- South River - Bridge in Harriston off U.S. Route 340.
S 4 - South River - Route 629 Bridge in Port Republic.
S 4A- Middle River - Route 629 Bridge in Port Republic.
S 6 - Middle River - Route 256 Bridge west of Grottoes.
S 6A- Middle River - Route 256 Bridge west of Grottoes.
S 8 - Grassy Creek (Black Run) - Route 867 Bridge east of Mt. Crawford.
S 9 - North River - Route U.S. 11 Bridge south of Mt. Crawford.
S 9B- North River - Route U.S. 276 Bridge in Rockland Mill.
S10 - South Fork Shenandoah - Route 659 Bridge north of Grottoes.
S11 - South Fork Shenandoah - Route 649 Bridge east of McGaheysville.
S12 - South Fork Shenandoah - Route U.S. 33 Bridge west of Elkton.
S13 - South Fork Shenandoah - Route 602 Bridge west of Shenandoah.
S14 - South Fork Shenandoah - Bixler Bridge.
S15 - Hawksbill Creek - Off Route 340 south of Luray.
S16 - Hawksbill Creek - Off Route 340 north of Luray.
S19 - South Fork Shenandoah - Luray Avenue Bridge in Front Royal.
S20 - South Fork Shenandoah - Route U.S. 340 Bridge in Front Royal.

LA - Laboratory accident

TABLE A-15

MONOCACY RIVER
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
9072919	7-28	1430	Sta MR 1	23	>160,900	>160,900	2.413	4.682	1.19	.357		20.0	5.43	7.59
20		1525	MR 2	23	>160,900	>160,900	2.148	2.246	1.32	.375		60.0	5.09	6.24
21		1350	MR 3	23	>160,900	160,000	2.000	2.846	1.42	.305		50.0	5.07	7.78
22		1330	MR 4	24	>160,900	160,000	2.698	3.246	1.43	.320		45.0	5.17	7.57
23		1310	MR 5	25	>160,900	>160,900	1.619	3.024	1.50	.217		30.0	5.61	6.32
24		1235	MR 6	24	91,800	54,200	1.979	3.330	1.66	.237		25.0	5.44	6.40
25		1155	MR 7	23	>160,900	>160,900	2,741	4.836	1.70	.400		15.0	5.56	7.48
26		1140	MR 8	23	>160,900	>160,900	1.810	2.964	1.79	.260		22.5	7.10	6.17
27		1130	MR 9	22	160,900	34,500	4.921	3.000	1.88	.375		40.0	6.76	7.56
28		1030	MR10	23	>160,900	160,900	2.233	2.352	1.23	.626		65.0	5.61	7.72
29		1005	MR11	21.5	>160,900	>160,900	.938	1.352	1.10	.226	13.50	60.0	6.08	5.75
30		0940	MR12	22	>160,900	>160,900	.779	1.482	1.33	.310	4.50	40.0	6.95	5.54
31		0920	MR13	22	91,800	34,800	.639	1.094	1.03	.221	6.00	25.0	5.22	4.19

MR 1 - Monocacy River - Md. Route 28 Bridge
MR 2 - Monocacy River - Fingerboard Road Bridge, Md. Route 80
MR 3 - Monocacy River - Md. Route 335 Bridge
MR 4 - Monocacy River - U.S. Route 40 Bridge
MR 5 - Monocacy River - Gas House Pike Bridge (Frederick STP)
MR 6 - Monocacy River - Md. Route 26, Ceresville
MR 7 - Monocacy River - Md. Route 550 Bridge
MR 8 - Monocacy River - Md. Route 77 Millers Bridge
MR 9 - Little Pipe Creek - Md. Route 194 Bridge
MR10 - Monocacy River - Md. Route 97 Bridge at Bridgeport
MR11 - Rock Creek - Pa. Route 134 Bridge at Barlow
MR12 - Rock Creek - U.S. Route 140 Bridge at Sheep Haven
MR13 - Rock Creek - Pa. Route 116 Bridge, east end of Gettysburg

TABLE A-16
MONOCACY RIVER
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69081937	8-18	1310	Sta MR 1	27	5,420	1,120	.836	1.156	.118	.010	102.00	15	11.08	6.97
38		1250	MR 2	26	91,800	17,200	1.123	1.321	.69	.022	108.75	25	7.48	5.09
39		1230	MR 3	25	>160,900	>160,900	1.050	1.536	.83	.406	42.75	150	3.72	6.35
40		1200	MR 4	24.5	>160,900	>160,900	1.019	1.524	.82	.390	45.00	150	3.64	5.75
41		1145	MR 5	25	>160,900	>160,900	1.414	1.917	1.03	.255	33.75	200	5.49	6.40
42		1115	MR 6	25	160,900	160,900	.763	.714	.84	.102	22.50	150	5.96	3.99
43		1045	MR 7	24.5	160,900	91,800	.479	.698	.91	.050	22.50	25	6.37	3.22
44		1000	MR 8	24	91,800	17,200	.105	.317	1.00	.045	13.50	10	6.83	1.83
45		1025	MR 9	23	>160,900	>160,900	2.714	3.428	2.03	.250	92.25	150	7.13	7.02
46		0940	MR10	25	13,000	2,200	.680	.838	.025	.039	24.00	2.5	6.10	3.44
47		0910	MR11	24	22,100	2,300	4.014	.610	1.98	.050	18.75	2	7.08	3.29
48		0850	MR12	24	17,200	4,900	13.597	7.251	2.8	6.35	12.00	8.5	2.74	>8.56
49		0830	MR13	23	34,800	17,200	.866	.902	1.54	.217	36.75	5	3.39	5.06

MR 1 - Monocacy River - Md. Route 28 Bridge.
MR 2 - Monocacy River - Fingerboard Road Bridge, Md. Route 80.
MR 3 - Monocacy River - Md. Route 335 Bridge.
MR 4 - Monocacy River - U.S. Route 40 Bridge.
MR 5 - Monocacy River - Gas House Pike Bridge (Frederick STP).
MR 6 - Monocacy River - Md. Route 26, Ceresville.
MR 7 - Monocacy River - Md. Route 550 Bridge.
MR 8 - Monocacy River - Md. Route 77 Millers Bridge.
MR 9 - Little Pipe Creek - Md. Route 194 Bridge.
MR10 - Monocacy River - Md. Route 97 Bridge at Bridgeport.
MR11 - Rock Creek - Pa. Route 134 Bridge at Barlow.
MR12 - Rock Creek - U.S. Route 140 Bridge at Sheep Haven.
MR13 - Rock Creek - Pa. Route 116 Bridge, east end of Gettysburg.

TABLE A-17

POTOMAC RIVER
JULY 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3 N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69073030	7-29	1320	Sta MP1	27	1,700	1,700	.326	.841	.307	.147	18.00	3.0	6.55	LA
32		1410	MP2	28	LA	LA	.210	.929	.220	.100	16.50	12.5	7.48	5.65
69072937	7-28	1350	MP3	26.5	790	700	.224		0.228	.075	8.25	6.5	6.66	4.29
69072932		1800	MP4		2,400	110	.242		0.43	.042	33.00	3.5	8.10	5.50
18		1450	MP5	28	4,900	490	.460		.430	.002	159.00		9.48	5.40
69072805		1200	MP6		7,000	3,480	.538	1.588	..838	2.55				
69073031	7-29	1335	CR1	28	2,400	200	.381	.859	.149	.183	11.25		4.89	3.65

MP1- Potomac River - Route 51, one mile SSE of Paw Paw, West Virginia.

MP2- Potomac River - One mile north of Brosius, West Virginia, near Bridge.

MP3- Potomac River - U. S. Route 11 Bridge at Williamsport.

MP4- Potomac River - Shepherdstown.

MP5- Potomac River - Point of Rocks.

MP6- Potomac River - Great Falls at Park.

CR1- Cacapon River - West Virginia, Route 9, 5 miles SSE of Paw Paw, West Virginia.

LA- Laboratory Accident

TABLE A-18

POTOMAC RIVER
AUGUST 1969
UPPER POTOMAC RIVER BASIN SURVEY
CHESAPEAKE TECHNICAL SUPPORT LABORATORY

Sample Number	Date Sample Taken	Time Sample Taken	Sample Location	Water Temp °C	Coliform MPN/100 ml	Fecal Coliform MPN/100 ml	Total P mg/l PO_4	TKN mg/l N	NO_2+NO_3 mg/l NO_3-N	NH_3 mg/l N	Chloro-phyll a ug/l	Tur-bidity JTU	DO mg/l	BOD mg/l
69081968	8-18	1740	Sta MP1	25	54,200	3,300	.241	.914	.187	.094	22.50	75	7.08	3.78
69		1900	MP2	26	2,400	IA	.259	.813	.255	.015	7.50	3	7.60	4.41
70		1030	MP3	26.5	2,400	170	.083	.787	.350	.048	7.50	3	6.74	1.72
71		0945	MP4	27	3,480	490	.163	.775	.408	.076	22.50	2	7.51	3.21
72		1330	MP5	27	22,100	5,420	.238	.978	.646	.038	54.75	8.5	9.09	3.71
01		1430	MP6	28	160,900	10,900	.297	1.016	1.318	.025	58.50	45	6.92	4.30
69081919		1800	CR1	25.5	27,800	170	.127	.711	.128	.016	3.00	6.5	7.98	3.21

MP1 - Potomac River - Route 51, one mile SSE of Paw Paw, West Virginia.
MP2 - Potomac River - One mile north of Brosius, W. Va. near Bridge.
MP3 - Potomac River - U.S. Route 11 Bridge at Williamsport.
MP4 - Potomac River - Shepherdstown.
MP5 - Potomac River - Point of Rocks.
MP6 - Potomac River - Great Falls at park.
CR1 - Cacapon River - West Virginia Route 9, five miles SSE of Paw Paw, West Virginia.

IA - Laboratory accident

TABLE A-19

UPPER POTOMAC BACTERIOLOGICAL STUDY

Fecal Coliform Density MPN/100 ml

July-September 1966

SAMPLE LOCATION	July 6-7	July 11-12	July 13-14	July 19-20	July 21-22	July 25-26	July 27-28	Aug. 2-3	Aug. 4-5	Aug. 8-10	Aug. 10-12	Aug. 15-16	Aug. 17-18	Aug. 22-23	Aug. 24-25	Aug. 29-30	Sept. 6-7	Sept. 7-8
Shenandoah R. at Harper's Fy. Park	2,120	4,800	330	5,400	>16,000	330	2,400	>160,000	5,400	1,300	16,000	1,700	1,100	5,400	1,700	2,200	54,000	1,600,000
Potomac R. at Harper's Fy.RR Br.	5,420	2,210	460	1,300	170	2,200	1,700	790	790	9,200	790	9,200	220	2,800	330	950	2,200	2,200
Potomac River at Shepherdstown	330	330	80	170	490	>16,000	1,300	490	78	2,200	1,800	1,400	140	950	460	170	5,400	700
Opequon Cr. below Martinsburg	34,500	5,400	2,400	5,400	2,200	11,000	2,200	9,200	2,400	9,200	17,000	35,000	1,300	3,500	2,800	5,400	11,000	3,500
Potomac R. at Williamsport	230	700	330	230	790	490	330	>16,000	9,200	9,200	330	5,400	790	5,400	2,200	330	1,100	1,700
Sideling Hill Cr. at U.S. Rt. 40	34,500	230	50	460	68	790	790	330	490	490	1,100			490	1,300	490	3,500	1,300
Potomac River at Hancock	170	220	80	110	170	700	230	9,200	230	490	330	1,300	460	330	330	68	1,100	230
Cacapon River at Great Cacapon	330	170	130	330	45	170	330	230	45	330	45	490	490	490	170	330	700	490
Great Cacapon at Bloomery, W. Va.	1,300	230	80	330	170	78	460	330	170	220	130	130	40	9,200	230	230	1,300	330
Town Creek at Oldtown	34,800	490	3,480	490	130	490	790	2,400	640	840	490			24,000	35,000	5,400	5,400	24,000
Little Cacapon at Higginsville	490	230	70	230	78	130	170	130	68	230	790	170	45	3,500	490	1,300	2,200	1,500
Passage Creek at Strasburg	490	2,210	790	490	790	3,500	1,300	490	170	9,200	2,400	1,400	330	2,800	490	1,300	1,700	2,200
N. Fk. Shenandoah at Edinsburg	1,720	10,900	5,420	>16,000	>16,000	3,500	17,000	24,000	5,400	>16,000	7,900	3,500	3,500					
S. Fk. Shenandoah at Cub Run	1,300	790	490	330	2,200	1,400	1,300	330	3,500	>16,000	2,200							
S. Fk. Shenandoah at Bentonville	50	2,100	220	790	790	16,000	460	700	1,100	790	1,100	490	170					

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